THE ENGINEER

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THE ENGINEER

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No. 5492 **APRIL 28, 1961** VOL. 211

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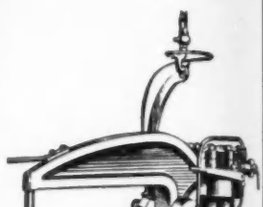

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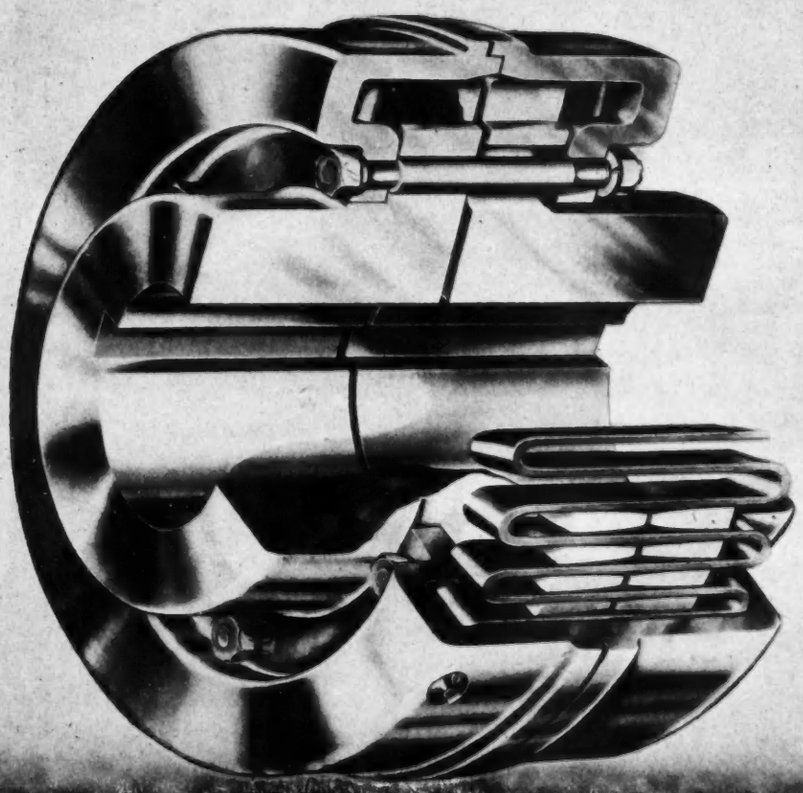

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THE ENGINEER

No. 5492 APRIL 28, 1961 Vol. 211

NOT A WHOLLY SATISFACTORY CONFERENCE

The organisation of a conference is less simple than it may often appear to some of those who attend it. There will, of course, be a general theme into which each of the papers presented must fit. That theme must be attractive and interesting in itself; and so must the individual papers be attractive and interesting in themselves. Providing the organisers can get into touch with "top" people in the subject to be covered there should be little difficulty so far. The real difficulty arises in choosing the subjects for the individual papers, in ensuring that their subjects do not overlap and in deciding how much time, if any, is to be allowed for discussion of individual papers. That the business really is tricky was demonstrated at Swansea last week when a two-day conference organised by the Department of Scientific and Industrial Research was held to discuss "The Problem of Communication" in science and industry. The subject was attractive enough and the quality of the papers presented was uniformally high. But we think that no one who attended the conference can have come away altogether satisfied that the affair was a success.

What went wrong? It is not easy to say. The conference got off to a good start; for Lord Brecon in opening it emphasised well some of the factors which were to be discussed. "The D.S.I.R. is deeply concerned with the difficulties of getting the results of scientific research and technological development accepted and exploited more quickly by industry. The reduction in time lag between technical advances and their industrial use depends not only upon improved methods of communication but also upon the ready co-operation of people in industry who are responsible for the adoption of new ideas. . . . With the growth of knowledge in technology it is clear that no firm, however large, can hope to supply itself from its own technical resources with all the technical information it requires. How much more true this is of the smaller firms. . . . The effectiveness of the communication between science and industry depends ultimately upon the attitudes of the persons concerned, both suppliers and receivers. The industrialist's search for information must be matched by eagerness on the part of the scientist to present the results of his investigations in the form most suitable for the enquirer." But thereafter the conference and the discussions lost cohesion and form. On the first day the subjects of the papers were: technical information and industrial innovation; the communication network in an industrial research organisation; and information—an educational problem; on the second day broad methods of communication were discussed and there were papers on the press, on exhibitions and conferences, on films, and on television. Two further papers covered technical liaison services and libraries. Somehow the discussion after each of the later papers on the first day seemed repetitive of that after the first; and the speakers tended to "waffle" about accepted truths rather than to pinpoint criticisms or bring forward any new ideas. On the second day when the subjects of the papers permitted even wider discussion there was even more "waffling" than on the first day. We may be wrong but we got the impression that one talkative member of the audience actually managed to make almost exactly the same contribution to the discussions no less than four times during the two days! What did go wrong? We suggest that the subject of the conference was too broad; and too broad in more than one sense. It ranged from quite detailed consideration of the problem of communication in a single firm to the discussion of the problem of "putting science across" to the public at large; it also covered or attempted to cover all industries from those relatively new ones which are based upon recent scientific discoveries to others predominantly based upon good established practice, offering or appearing to offer less scope for the application of research results. The conference even opened up that subject upon which everyone seems to have something to say, education. For a conference to be a success we suggest it must attract a more or less homogeneous audience to discuss a rather limited field and each paper should lead to a discussion sharply delimited to its own field. But if the proceedings in the conference hall at Swansea thus fell short of real success we have no doubt that the affair had the hidden value, which such affairs usually have, of bringing together into private discussion people who would not otherwise have met; and if some of these private discussions had very little relevance to what went on in the hall, what of it?

COAL RESOURCES

As a result of research and investigations which have been in progress for more than thirty years the National Coal Board now has at its disposal a series of maps and diagrams giving a clear and comprehensive picture of the coal resources of this country. The Coal Survey Organisation was created in the 1920s as part of the Department of Scientific and Industrial Research for assessing the extent and the characteristics of the national coal resources, and it was taken over by the N.C.B. in 1947. The survey entailed the investigation of several hundred geologically distinct coal seams—some of which extend over hundreds of square miles, and some of which are either being worked or are potentially workable. Analyses of over 20,000 coal seams were obtained and many thousand measurements of seam sections were made. From the information thus derived the properties of the major coal seams have been mapped.

To-date folios of maps of the characteristics of at least one seam from each of the nine divisions of the N.C.B. have been compiled and in all about 180 seams of importance have been covered. Each set of maps is supplemented by a table of representative analyses of the coal seam at different localities with a text amplifying the information which cannot be shown graphically. The properties dealt with are those which determine the value of a seam as a new material — structure and extent as a workable deposit; nature of the pure coal; and the amount and nature of the impurities within the coal. The nature of the coal is dealt with in terms of its "rank," which reflects its maturity and represents the position occupied by the coal in the series: anthracite—low volatile steam coal—carbonisation coal—high volatile general purpose coal. Rank expressed in one way or another is the most common basis of coal classification. Calorific value moisture-holding capacity, carbon content, hydrogen content, volatile matter and coking properties are all related to rank and are all amenable to mapping.

The detailed information available on the maps is expected to remove much of the uncertainty which existed in coal-mining due to the variability between coal seams and in the seams themselves. Transparencies which are provided in the folios outline old and existing workings, and they can be kept up to date to show at any time the pattern of change, indicate unworked areas and enable the potential of a seam or area to be determined. By reference to the maps advance planning will be simplified to ensure that the right types of coal will be produced in the required quantities to suit future markets. In all industries forward planning of capacity to comply with market requirements is essential economic practice. Now that the N.C.B. has this knowledge of its resources it would seem that an important step has been taken towards more economic production and its aim to provide for a market for 200 million tons of coal a year.

SHIPBUILDING PROSPECTS

The report just published of the Sub-Committee of the Shipbuilding Advisory Committee considers the importance of the industry and values the 1958 turnover at £370 million and the net output at £200 million, which was almost 3 per cent of the net output of the manufacturing industry of this country. Those engaged in shipbuilding at the end of 1960 numbered nearly 85,000, including 12,500 engaged on naval work, while the employment level in ship-repairing was 50,000. During the years 1950 to 1960 the annual output from British yards was constant at about 1,400,000 gross tons, whereas the world total of tonnage launched rose from 3,500,000 to 8,300,000 so that this country's share dropped to 16 from 37 per cent, although its value per ton was the highest in the world. The report points out that there is an excess of shipbuilding capacity and that new maritime countries have acquired national fleets and established their own shipyards, public funds bearing part of the cost, while established maritime countries have expanded their yards. This position, coupled with trading restrictions, barter agreements and special financial arrangements, has restricted the traditional outlets for British yards.

Turning to the prospects of shipbuilding, the size of the order book at the end of 1960 is given as 3,200,000 tons gross and it is suggested that future requirements for British owners may be assumed as 1,000,000 tons gross per annum. Over the next five years the report estimates orders for non-tanker tonnage at 2,500,000 tons, tankers at 1,500,000 tons and some 750,000 tons to foreign account making a total of 4,750,000 tons gross which may be built in the years 1961 to 1965 inclusive. It warns that to obtain this work the industry must be fully competitive. Although conceding that many yards are efficient it is emphasised that in the present state of fierce competition even marginal improvements are of importance. Fixed price is another requirement, especially in a buyers' market, but the report notes that a great part of the cost of a ship is represented by materials and equipment bought in, and asks the manufacturers concerned to give fixed and competitive quotations. Another point made is that delivery dates should be kept and that stoppages are more frequent in this country and that the consequent delays have been detrimental to this country's interests.

The terms of credit offered are generally decisive in placing an order and the report comments that credit is available on better terms abroad with consequent loss of orders to competitors in other countries. Improved and cheaper facilities offered by E.C.G.D. are welcomed, but it is stressed that shipbuilders must be in a position to quote competitively at the opening of negotiations and not endeavour to match terms at a later date. The investment rate in the industry during recent years is stated. That for 1958 was £18,500,000, equivalent to 5 per cent of turnover or 9.5 per cent of net output in that year. Finance for the modernisation programmes has been provided from our industry's own resources whereas the industry in many countries has been able to use tax-free investment reserves. Furthermore, several governments provide shipbuilding subsidies and these often divert orders from builders in this country.

On the subject of labour relations the report notes the many disputes, and the resultant disruption of work schedules, and that these difficulties do not occur to the same extent in foreign yards. Established traditions often negative a change in production methods, but in the present deteriorating position it is felt that improvements in this direction must be made or worse conditions will result to the detriment of all. The report stresses the need of managements to strive to improve labour relations and understanding and so create greater trust, while trade union leaders must, on their part, impress upon their members the seriousness of the position and the importance of co-operation in adopting new techniques. The re-inauguration of joint yard consultative committees is also recommended. On the question of rationalisation the report expresses the view that there is no need for any major reduction in capacity provided that the recommendations are carried out effectively. However, managements are advised to consider the possible benefits of amalgamations.

The facts and figures given in the report indicate that the shipbuilding industry must face the hard facts of existence and that survival is dependent upon many factors of which a major one is co-operation of management and labour in keeping employees informed, if only to prevent the spread of canards which often lead to unofficial strikes. It is also essential that the most efficient methods of production should be achieved and perhaps in this respect there may be amalgamations between unions together with a rewriting of rule books to eradicate the out-of-date and remove the causes of

demarcation disputes. Although many yards have been strike free it cannot be ignored that there have been several strikes elsewhere of a major character over comparatively minor matters, plus many small stoppages. All these represent waste through loss of wages, loss of production, and disorganisation of work programmes involving unemployment in other trades. Setbacks, however small, are cumulative in effect and are translated into increased cost and loss of competitive power, while the ship owner is also involved in loss of earnings through delay in delivery of a ship. Thus the source of shipbuilding orders is affected adversely.

The existence of national fleets, for prestige purposes, and of national shipyards plus expansion of facilities in other countries has created an overall shipbuilding capacity approximately twice that required. These circumstances mean a definite shrinking of our export market and intensified competition for those orders offering, and are hard inescapable facts which the industry must accept and face. Another factor to be remembered is that with the increased speed of ships, fewer ships can carry the same amount of cargo, although this effect is offset by the fact that more voyages per year does mean a longer time in port and that world trade is increasing. It is made clear in the report that the credit terms available in other countries cannot at present be matched in this country and it is to be hoped that the Government takes a realistic view of the position and makes finance available to enable our shipbuilders to negotiate on terms of equality with builders in other countries, both for orders for export and for British shipowners. Although orders for foreign accounts do earn foreign exchange, ships built for British owners contribute to the balance of payments each year. When it is remembered that only 49 per cent of our imports in 1960 was carried in British ships there would appear to be very cogent reasons why measures should be taken to prevent British ships from being pushed off the sea trade routes and so encourage British owners to place orders for new ships and be confident of their future employment. Although some degree of rationalisation may be eventually found to be necessary should the steps, essential to ensure full competitive power, not be taken, nationalisation is no panacea whatever. This would merely add to the top hamper, and such additional top weight would make the industrial ship unstable so that compensating ballast would be necessary. Thus the industry would require to be subsidised; so that instead of making profits and contributing to the country's revenue it would be a source of increased expenditure.

PLEA FOR PEDESTRIANS

Last week the Pedestrians' Association for Road Safety held its annual conference at the Royal Festival Hall in London. The theme of the conference was a "Pedestrians' Bill of Rights." The Bill sets out physical measures that the Association believes can be taken relatively quickly and cheaply to make the existing road system safer and more tolerable for pedestrians and it also suggests the safety standards and principles that should guide future highway developments. It is interesting to compare the phraseology of this Bill with that of some of the speakers at a meeting last month of the Parliamentary and Scientific Committee, all of whom were concerned with some aspect of research into road safety. In the Bill the word "must" is repetitive. "The motorist must be treated as a licensee who holds his licence during good behaviour. . . . The speed limit must be properly enforced. . . . Motor traffic must be excluded from many shopping streets. . . . More zebra crossing must be provided. . . . There must be more street refuges . . . " etc. But before the P. and S. Committee we doubt whether the word was ever mentioned. Instead there was constant reference to scientific studies of the influence of a variety of factors on the occurrence and the severity of accidents. Frankly we think the studies of the Road Research Laboratory, of the Road Injuries Research Group of Birmingham Accident Hospital, and of the Motor Industry Research Association, all of which were concerned, are much the more effective contributions to road safety. The comparison illuminated the difference between the analytical approach which sets out to discover how people do behave and the emotional approach which wishes to force people to behave in a particular way.

Nevertheless the Bill of Rights, despite its inclusion of certain impractical or needless provisions — such as that for the setting up of a Ministry of Road Safety — does express some of the ways in which the need to provide for motor traffic has impinged on the freedom of pedestrians to go about their businesses in convenience and safety. And are we not all more often pedestrians than motorists? A study of the Bill will surely prove valuable to engineers, architects and, traffic engineers (who need to study pedestrian movements as well as vehicle movements). For it is in effect the plaint of the pedestrian against the conditions, particularly in built-up areas, being imposed on him by the motorist. Good modern design, particularly of the kind which segregates the two traffics, ought to make it possible to eradicate many of the grievances mentioned in the Bill.

The Engineer—100 Years Ago (APRIL 26, 1861)

"Trial of a Land Steam Fire-Engine"

"A highly satisfactory trial with a new land steam fire-engine took place on Saturday, . . . at the New River Head, Amwell Street . . . The engine has been constructed by Shand and Mason, of the Blackfriars-road, for the London Fire Brigade. It is mounted on high wheels and springs, so as to be drawn rapidly by horses, and carries the hose and implements, with the firemen, upon it. Upon an alarm of fire being given the fire is lit, the steam raised, and the engine ready for working in thirteen minutes. The weight, including the water, is 6,499 lb.

"The first point to be ascertained was the time occupied in getting up steam after applying a light to the fire, the boiler and water being quite cold; the following was the result: steam of 30 lb pressure in 12¼ minutes; 40 lb, in 13 minutes; 50 lb, in 14 minutes; 60 lb, in 14½ minutes; and 70 lb, in 15 minutes. The engine was then set to work through 210ft of hose, a jet 1¼in diameter being used; the test for height was a steam engine chimney 134ft high, close to which the jet-pipe was placed. There was a considerable breeze blowing at the time, but, notwithstanding, the elevation attained, was at least 26ft above the chimney, making a total height of 160ft. The jet-pipe was then depressed to ascertain the horizontal distance the same quantity of hose and the same jet-pipe being used when the measured distance was found to be 202ft."

Engineering and Marine Exhibition

No. III.—*Continued from page 644, April 21, 1961*

In opening the Engineering, Marine, Welding and Nuclear Engineering Exhibition at Olympia last week Mr. A. J. Baker, Honorary President of the Exhibition, pointed out that the mechanical and electrical exports from the country last year were valued at nearly £1000 million, or over one-quarter of the total exports. The exhibition, which covers representative products from the whole field of the engineering industry, provides an excellent opportunity to inspect the many developments, and give some indication of the efforts made by manufacturers to promote and increase our export trade. In this article we continue our descriptions of some of the exhibits, selected to show some of the latest plant and the scope of the exhibition.

John Thompson, Ltd.

A variety of products is exhibited by the John Thompson Group of Companies to illustrate the design and manufacturing facilities available within the organisation. The industrial steam raising plant includes a model of the " Multipac " wet back package boiler which represents the range manufactured by the John Thompson Package Boiler Division, covering an evaporative range of 2000 to 18,500 lb per hour from and at 212 deg. Fah. The standard boiler is designed for oil burning, but a modified model is available for coal firing. It has a dished-end wet-back combustion chamber which eliminates the need for refractory linings and brickwork, and the three-pass gas circuit promotes rapid circulation, with high thermal efficiency. All fuel oils up to 3500 seconds viscosity can be burned, without need for any pumping and heating when the fuel storage tank is located adjacent to the boiler-house.

For the smaller user requiring fully automatic control when burning heavy oil, the firm introduced the " Demipac " package boiler, covering a range of 500 lb to 3500 lb per hour evaporation from and at 212 deg. Fah. This boiler set is fully automatic, with pumping and heating equipment, ignition control and necessary safety devices. Its pressure-jet air blast atomising burner is designed to operate on 950 seconds fuel oil.

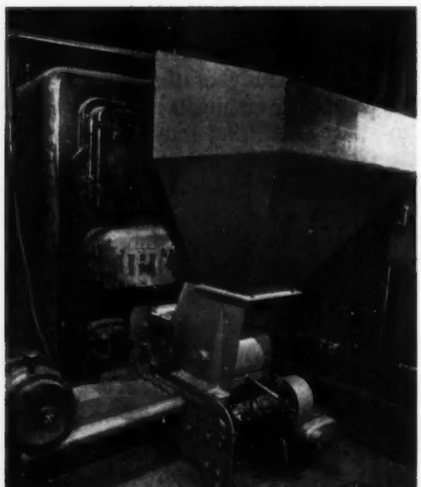

Fig. 71—Travelling grate " Mini-Stoker " for small boilers—Thompson

A front section of a " Demipac " exhibited (Fig. 71) is fitted with a " Mini-Stoker," manufactured by John Thompson (Triumph Stoker), Ltd. This travelling grate stoker for the smaller shell and sectional boilers is designed to burn the cheaper grades of coal now obtainable, meeting the requirements of the Clean Air Act. It is driven by a fractional horse-power motor and embodies a forced draught fan giving effective air distribution by an arrangement of dampers in the stoker chassis. The stoker can be fitted with semi- or fully automatic controls which can be set to give any required rate of output up to boiler rating. A thermostat or pressurestat governs the stoker to ensure that a preset output temperature or pressure is maintained.

A working model of a vibratory ash extractor shown is an improved alternative to the more conventional systems of ash removal from shell boiler installations. Basically a shallow tray, the extractor extends from a point beyond the rear of the stoker to the front of the boiler flue. It is fitted in the space between the underside of the stoker frame and the bottom of the flue and mounted on a chassis which is firmly attached to the flue bottom. The ash is directed by deflector plates on to the vibrating tray, along which it is transported and discharged into a receptacle or conveyor at the front of the boiler.

The special purpose plant exhibited includes the control drive gearbox we illustrate in Fig. 72. It is one of two similar units being supplied for the Berkeley nuclear power station and is an integral part of the visual observation and removal equipment which is provided to meet the possibility of mishaps or failure of the control rods or fuel elements and associated equipment. This gearbox manufactured by John Thompson Ordnance Company is made up of aluminium castings containing a main lay-shaft and two banks of five cross shafts. Five drives pass vertically from the gearbox and five pass horizontally, only one drive being selected and connected at any time by individual clutch and selector mechanisms, and individual output drive locking brakes. The selector and clutch drive arrangement enables a drive selector pinion to depress a spring plunger through a bore in a clutch operating pinion, thence connecting it to a keyed flange which is turned to engage the clutch. As the individual drive is engaged, its cam contacts a micro-switch which selects motor speed and direction, indicates " drive engaged," and releases the individual locking brake.

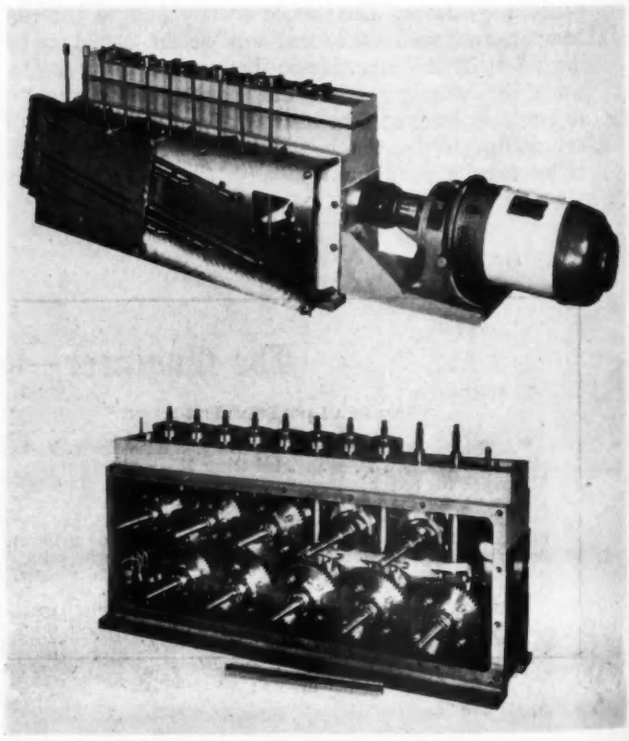

Fig. 72—Gearbox for visual observation and removal equipment at Berkeley nuclear power station—Thompson

Newalls Insulation Company, Ltd.

In addition to its range of thermal and sound insulating products Newalls Insulation Company, Ltd., Washington, Co. Durham, exhibits representative examples of polyurethane pipe sections. This material is very light and has high structural strength combined with a low thermal conductivity which suits it for low temperature piping systems. In the form of foam, polyurethane is being used increasingly in refrigerated ships and cold stores for insulation purposes. As a foam it can be dispensed or poured as a liquid mix into cavities, then, as it foams, the liquid expands to follow the contours of a cavity to ensure intimate contact and good insulation. Spraying techniques have also been developed for covering tanks and vessels with polyurethane.

Leyland Motors, Ltd.

A number of diesel engines suitable for powering a wide range of plant are exhibited by Leyland Motors, Ltd. They include, in addition to the "Argonaut," shown in the page of engines in our issue of April 14, the six-cylinder UE 350 unit equipped with a 13in three-element single-stage torque converter. This converter is based on the Schneider system and has been designed and produced by Leyland Motors, Ltd., in conjunction with Self Changing Gears, Ltd. It is an automatic hydraulic transmission with variable speed and torque ratios, and combines a hydraulic torque converter and a hydraulic coupling into a single unit. The engine has a bore and stroke of 3·96in by 4·75in and a maximum rating of 95 b.h.p. at 2400 r.p.m. and a maximum torque of 245 lb feet at 1400 r.p.m. Another engine on view is the 400-S direct injection four-stroke unit, illustrated in Fig. 73, which has six cylinders of 4·22in bore by 4·75in stroke, and develops 125 b.h.p. at 2400 r.p.m. and a maximum torque of 300 lb feet at 1600 r.p.m. The cylinder block and crankcase are machined from a single casting and incorporate pre-finished dry thin-wall porous chrome steel liners. Six high tensile steel studs disposed around each bore secure the cylinder head, and the nitride hardened crankshaft, machined from a chrome-molybdenum forging, runs in seven thin-shell indium coated lead bronze bearings. A compressed rubber damper at the front of the engine minimises vibration. The pistons are of a high silicone alloy and have a "Spheroidal" combustion chamber machined in the crown. A Simms "Minimec" multi-element fuel injection pump with mechanical flyweight governor is fitted and used with Leyland four-spray injectors. Also on view is a self-contained power pack equipped with a P.U. 680 engine rated at 160 b.h.p. at 2100 r.p.m. and an Auto-Diesel generator incorporating a six-cylinder U.E. 902 unit and having a rating of 145kVa at 0·8 power factor.

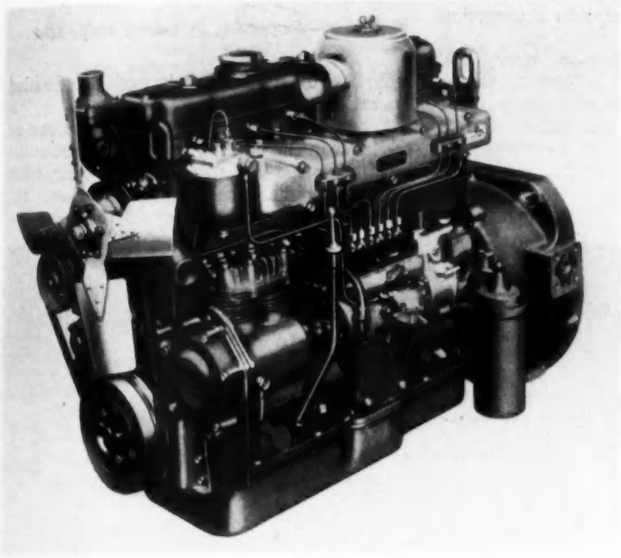

Fig. 73—Six-cylinder o.h.v. 400-S, "Power-Plus" diesel engine—Leyland

F. Perkins, Ltd.

Industrial engines ranging from the Four-99 unit of 34 b.h.p. to the Six-354 unit rated at 112 b.h.p. are shown on the stand of F. Perkins, Ltd., together with marine diesel engines covering a power range of 21 to 120 s.h.p. Exhibits include the P3/144 engine, having a rated output of 21/37 s.h.p. at 1200/2250 r.p.m., and the S6 (M) developing 68/120 s.h.p. at 1200/2100 r.p.m. Examples of the 6 h.p., 16 h.p., 35 h.p. and 40 h.p. outboard petrol motors are displayed, and also a Perkins "Mars" gas turbine instruction set which is intended for use in universities and technical colleges. This set consists of a 50 h.p. "Mars" gas turbine fitted with a dynamo-meter and other special equipment for measuring performance. A "Mars" gas turbine able to run equally well on diesel fuel, paraffin or low-grade petrol is also on view, together with a "Mars" gas turbine water pump which delivers 500 gallons per minute at 100 lb per square inch. A new power pack exhibited incorporates a direct-injection, six-cylinder, 5·8 litre Perkins Six-354 diesel and is rated at 104 b.h.p. at 2400 r.p.m. for intermittent use and at 85 b.h.p. at 2000 r.p.m. for continuous operation. The engine employs a mechanical governor incorporated in the vertically mounted rotary distributor pattern fuel injection pump. Bore and stroke are 3⅞in by 5in and the engine has pressed in dry cast iron liners, thin wall pre-finished main bearings and a seven-bearing crankshaft. The Six-354 unit is available in every stage from a basic industrial engine to a complete power pack with canopy as shown in Fig. 74. The complete pack is equipped with radiator, fuel tank, fuel oil piping, instrument panel, 12V starting equipment, air cleaner, silencer and detachable side panels.

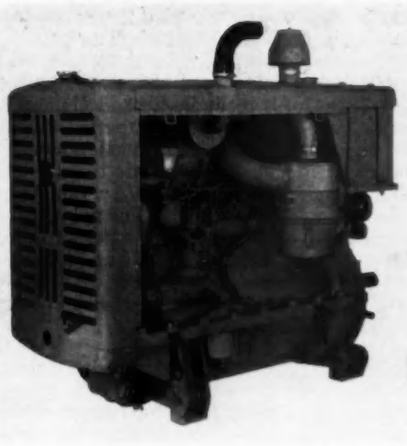

Fig. 74—Power pack incorporating a Six-354 industrial diesel engine—Perkins

Harland and Wolff, Ltd.

Exhibits representative of the wide variety of products manufactured by the company are shown on the stands of Harland and Wolff, Ltd. A model of the 45,000 ton P. and O. liner "Canberra," now nearing completion at Belfast, represents the ship-building division. Typical of the range of diesel engines built is a three-cylinder unit having a bore and stroke of 250mm by 300mm and rated at 140 b.h.p. at 600 r.p.m., and a model of a two-cycle, single-acting opposed piston crosshead engine. This opposed piston engine has six cylinders of 750mm bore by 2000mm combined stroke and is equipped with two exhaust gas-driven turbo-blowers supplying air for pressure induction and for scavenging.

The company also shows an EM-2 three-stage Harland and Wolff-Cooper-Besemer compressor (illustrated in Fig. 75) which has a high duty cast iron box frame open at the top to admit the crankshaft. This forged steel crankshaft is counter-weighted and runs in white metal lined bearings. The compressor cylinders are designed for low vacua or for pressures ranging up to 6000 lb per square inch and have bodies of special duty cast iron, while the piston rod is of high tensile alloy. Also exhibited is a three-cylinder diesel engine of 256mm bore by 300mm stroke and developing 140 b.h.p. at 600 r.p.m., and examples of d.c. and a.c. motors and also of d.c. and a.c. starters together with an engine-driven alternator rated at 600kW 415V, 50 c/s at 333 r.p.m.

Fig. 75—Mark EM-2 horizontal compressor—H. and W. Cooper-Bessemer

Martonair, Ltd.

Pneumatic equipment with representative examples of its application in many fields is displayed on the stand of Martonair, Ltd., Parkshot, Richmond, Surrey. The exhibits include the positional controllers developed by the firm to meet the instrumentation requirements in various industries and for the control of special purpose machinery.

Normally a positional controller is itself controlled by a variable pressure air supply, varied sometimes manually, but more often by an instrument dependent on the application. Generally, a cylinder with a positional controller is used where a magnitude or quantity has to be varied continuously. One of the most common applications, therefore, is in connection with air-operated valves, shutters, &c., and for speed variators and burner control. A complete assembly comprises a standard control unit mounted integral with a standard "Martonair" cylinder of any type and size of 2in bore and over. The cylinder operates at normal air pressure of 80 lb per square inch and the control pressure may be anything from 3 lb to 80 lb per square inch. Three positioners covering various ranges of control pressure are available. Control units can also be mounted integral with one of the maker's torque units to provide rotational motion proportional to the control pressure. This combination provides a convenient means of operating mechanisms requiring a rotary motion, and standard torque units are available providing up to 360 deg. rotation and torques up to 1000 lb ft.

Fig. 76—Air line filter—Martonair

A range of impact cylinders is now made for use with standard valve equipment, and in capacities of $^1/_{10}$ to 2 ton-in. The 1 ton-in capacity impact cylinder is suitable for delivering a maximum blow of 20 tons and with an air supply of 80 lb per square inch will at a single blow punch a 1in diameter hole in a $\frac{1}{8}$in thick mild steel plate. The return thrust is approximately 2000 lb at this supply pressure and speeds of thirty blows per minute are easily obtained. These units are suitable for all types of press work and can be built-up into presses, built into existing machinery, adapted for additional subsidiary operations on existing presses or used to convert fly and kick presses. The impact blow delivered may be readily varied to suit different applications by incorporating a standard air pressure regulator which will give direct control.

A recently introduced design of air-line filter (Fig. 76) is made in $\frac{1}{4}$in and $\frac{1}{2}$in B.S.P. sizes. The swirling effect imparted to the air on entry gives a centrifugal action to throw water and dirt outwards to gravitate down the sides of the bowl into a sump and the air then passes through a fine nylon mesh which removes the remaining water and dirt. Each filter bowl is fitted with an indicator —a red ring normally masked by a black band—which becomes visible when emptying or cleaning is necessary.

William Kenyon and Sons, Ltd.

The power transmission equipment being demonstrated by William Kenyon and Sons, Ltd., Dukinfield, includes a "Powergrip" drive which uses a toothed belt running on grooved pulleys at speeds up to 16,000ft per minute. With this design of belt compact drives with pulleys at short centre distances can be arranged and ratios of up to 12 : 1 can be achieved. This drive, made in five pitches, is suitable for applications up to 600 h.p. A typical installation shown, in Fig. 77, is used to transmit drive from a 15 h.p. variable speed motor to a punching machine.

A shaft-mounted reduction gear box known as the "Shaft King" made under licence by the firm is of concentric shaft construction. It can be fitted with a positive mechanical overload release to protect a driven machine and a back-stop to prevent reverse movement in plant in the event of drive stoppage. These speed reducers are made in six sizes and two ratios of 13 : 1 and 20 : 1.

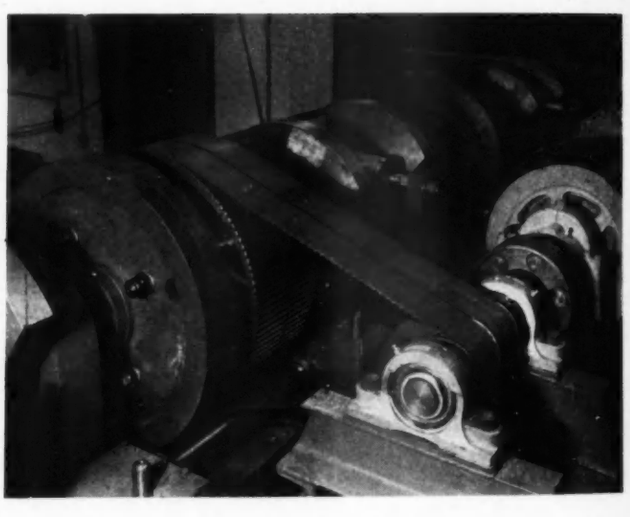

Fig. 77— "Powergrip" drive from 15 h.p. variable speed motor to a punching machine—Kenyon

A new coupling known as the "Flexsil" is made for drive applications up to 100 h.p. It enables angular misalignment of up to 5 deg. to be accommodated and has good damping properties. Power is transmitted through a flexible rubber disc moulded round synthetic tension members.

Ronald Trist and Co., Ltd.

A recent development of Ronald Trist and Co., Ltd., Bath Road, Slough, Bucks, is a sequencing blow-down cock for use on boiler, feed-water level controls and alarms. This cock (Fig. 78) is ratchet operated so that the correct procedure for blowing down the float chamber must always be followed. It is made in six models for working pressures up to 250 lb. per square inch, with right-handed and left-handed operation.

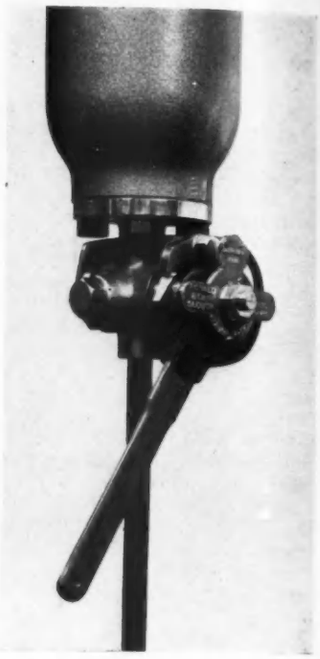

Fig. 78—Sequencing blow-down cock—Trist

When blowing down the first movement of the lever in turning the cock plug releases the locking device, isolates the water connection from the boiler shell and blows down the float chamber bringing the level control or alarm to the "failed safe" position. Subsequent movement of the lever in turn isolates the float chamber, blowing down the water connection between the cock and the boiler shell, then blowing both together. When the lever finally returns the cock to the normal operating position a locking pawl engages in a cam plate to indicate that the sequence has be completed. A "tee" shaped plate on the front of the cock shows the corresponding flow position of the plug ports.

A working demonstration has been arranged of the latest "Mobrey" modulating level controller which is primarily intended for fitting on boilers to maintain the water level in relation to the rate of evaporation. This equipment now incorporates a low-water alarm and cut-out switch and, when used with a vertical electric alarm, assists in meeting the requirements for automatic unattended steam boilers.

Sharples Centrifuges, Ltd.

The oil purification equipment made by Sharples Centrifuges, Ltd., Doman Road, Camberley, Surrey, includes the continuously operating, self-cleaning "Gravitrol Nozljector" developed particularly for marine use with heavy fuel oils. The "Gravitrol 2000" which was first introduced by the firm provided for the treatment of up to 144 tons a day of heavy fuel oil. Now, to meet a demand for a smaller equipment to handle up to 60 tons a day, the "Gravitrol 1000" has been developed and it is intended to satisfy the requirements of ships of up to 12,000 b.h.p.

We reproduce a diagram of the "Gravitrol" nozzle re-cycle bowl to give a general impression of the system. The bowl would appear to be similar to that of a clarifier re-cycle nozzle centrifuge, but it incorporates a re-cycle dam system so proportioned that the bowl only accepts sufficient re-cycle water to maintain the interface outside the

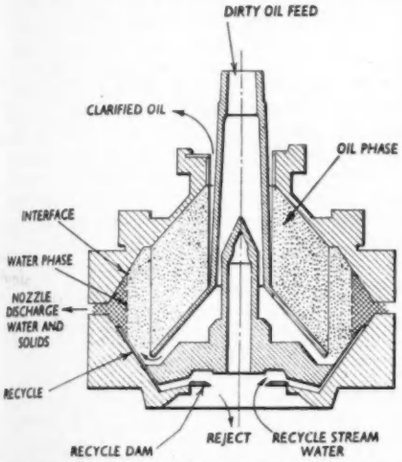

Fig. 79—Diagram of the "Gravitrol" nozzle recycle bowl—Sharples

disc stack. All of the water and solids leave the bowl through nozzles located at the point furthest from the treated oil outlet. The re-cycle dam is selected on the basis of the desired interface position and the gravity and temperature of the oil feed.

In practice oils of different gravity can be fed to the centrifuge, thereby tending to change the interface position. This could be overcome by changing the dam—which would involve stopping the centrifuge. To overcome this necessity there has been adopted what is termed a "Thermal Dam" principle using the fact that the gravity of water varies with temperature. This principle is applied to the re-cycle water stream and its temperature—hence its gravity—is raised or lowered as the specific gravity of the oil feed varies. In this way the position of the interface is stabilised irrespective of variations in oil feed without need for mechanical changes.

David Brown Industries, Ltd.

Examples of the standard and special gearing made by David Brown Industries, Ltd., of Huddersfield, include a three-layshaft co-axial helical unit for turbine drive applications, which is typical of the multi-layshaft designs developed to meet the high ratios involved in turbine drives whilst keeping peripheral velocities down to reasonable proportions. This gear was supplied to Ruston and Hornsby, Ltd., for a turbo-alternator drive in a marine installation and transmits 1200 h.p. while giving a speed reduction from 13,000 r.p.m. to 1800 r.p.m.

In this compact design of gear unit there is no need to provide a high-speed bearing as there are no transverse forces acting upon the input and output shafts. The low-speed bearing, which normally carries the weight of the gear assembly and acts as a location bearing, can be used to support one end of an adjacent piece of equipment such as a generator armature. The three-layshaft assembly exhibited also incorporates the drives for a ship's fuel and lubricating oil supplies, tachometer, governor and an overspeed trip mechanism.

The new range of "Radicon" worm reducers is represented by two basic types—the "Adaptable" spanning the range from 1⅛in to 3⅜in gear centres, and the "Solid Foot" series ranging from 4in to 8in centres. There are seven and five sizes respectively in the two ranges, which are to be progressively extended.

A more recent introduction to this firms' products is a double volute centrifugal pump made under licence from the Bingham Pump Co. of the United States. These horizontal single-stage pumps are so designed that the hydraulic pressure on the case is balanced at all diametrically opposite points around the periphery of the impeller throughout the operating range.

Sir George Godfrey and Partners (Industrial), Ltd.

Last year two new products of interest were introduced by Sir George Godfrey and Partners (Industrial), Ltd., Hanworth, Middx. —a screw type compressor for industrial applications and a mechanical torquemeter. The compressor was developed to meet a need for a machine capable of delivering oil-free air at pressures up to 30 lb per square inch without resorting to two-stage Roots installations. It is made under a licence acquired from Svenska Rotor Maskiner of Stockholm and incorporates a number of developments of the British company.

The new compressor, to be seen in Fig. 80, was described in some detail in our issue of December 2, 1960, and the model now available delivers up to 450 cubic feet of air a minute at 30 lb per square inch. It is surge-free in operation and, having no reciprocating parts, is free from any vibration when running. Such screw compressors have a high volumetric displacement for a given size and can operate over a wide band of pressure ratios without a significant loss in efficiency. They run at up to 30,000 r.p.m. and as there is no contact between the rotors or between the rotors and casing, no internal lubrication is required—effective sealing being provided by small running clearances. The male rotor is driven and takes the full driving torque, the female rotor being driven by timing gears and acting as a rotary seal.

A standard synchronous motor is generally used for driving these compressors and to provide the necessary speed increase the compressor is mounted on and driven through a step-up gearbox.

The torquemeter is a compact instrument which can be installed between the output shaft of a prime mover and the input shaft of a driven machine. It measures torque from zero to 850 lb/ft in a speed range of zero up to 25,000 r.p.m. The mechanism is designed to magnify the twist of a torsion bar under load through an epicyclic gear train and gives a continuous reading of the prime mover output.

This firm's recently introduced "Godfrey/Waterous" pump is a rotary, positive displacement machine, similar in general configuration to the firm's industrial blower. It is stated to successfully handle a variety of materials from light petroleum products to molasses or asphalt cement. As with the Roots blower, there is no contact between the rotors or between the rotors and the rotor casing, and no lubricant is needed in the rotor chamber.

Rolls-Royce, Ltd.

On the stand of Rolls-Royce, Ltd., Oil Engine Division, there will be shown two generating sets, one being a Campbell and Isherwood compound-wound generator producing 220kW 110V when driven at 1800 r.p.m. by an eight-cylinder, turbo-charged and inter-cooled diesel engine to which it is flange connected and flexibly coupled. The second set consists of an eight-cylinder, turbo-charged unit which is coupled to a MacFarlane self-regulating alternator giving a net output of 212·5kVA at 0·8 power factor, 440V, three-phase, 60 c/s. A Bryce Berger hydraulic starter is fitted in addition to the electric starter and cooling is by remote mounted radiators equipped with automatic starting electric fans. One of the Rolls-Royce Mark IV diesel engines having individual four-valve cylinder heads and pistons of improved design is also shown. This is a six-cylinder, turbo-charged, four-stroke, direct injection unit of monobloc construction and having a bore and stroke of 5½in by 6in. The engine gives 20 b.h.p. more than the standard unit by reason of the improved gas flow to and from the combustion chambers through the four valves. New pattern pistons of improved material are fitted and have a cast iron insert for the top compression ring groove.

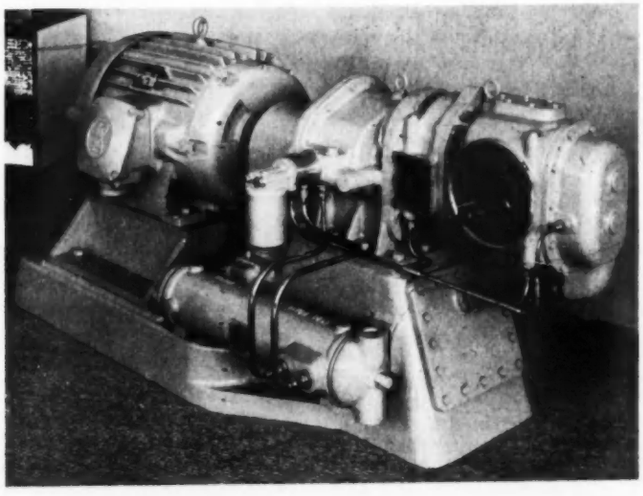

Fig. 80—Air compressor set for delivering up to 450 cubic feet of oil-free air per minute at 13 lb per square inch—Godfrey

Portable Welders, Ltd.

The spot welding equipment demonstrated by Portable Welders, Ltd., Castle Mills, Buckingham, Bucks., includes a new hand-operated production gun. This gun, as shown in our illustration (Fig. 81), is suspended from a spring loaded counterbalance on a sling giving either a 180 deg. or a full turning circle; it can also be mounted on a pedestal for operation as a conventional machine.

The gun is rated by the manufacturers on a 20 per cent duty cycle at 10kVA—the normal rating on a 50 per cent duty cycle to B.S.S. 3065 would be 25kVA. It is normally capable of welding up to two $\frac{1}{8}$in mild steel parts, but it is stated that in production a maximum of $\frac{1}{4}$in to 1in is being satisfactorily welded. We are informed that on 14 S.W.G. mild steel, continuous production rates of 1800 spots per hour can be achieved, with up to 2500 an hour on 18 S.W.G. and lighter

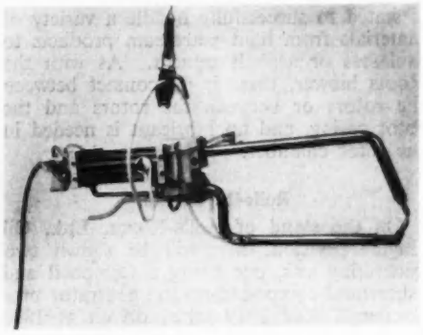

Fig. 81—Hand operated spot welding gun fitted with special arms giving a reach of 20in with a throat depth of 9in—Portable Welders

gauges. The gun will also weld non-ferrous materials satisfactorily, and production welding on 2 by 16 S.W.G. aluminium is possible, with intermittent work on 2 by 14 S.W.G. The standard range of water-cooled arms available have an 8in, 12in or 18in reach and 4½in throat depth. Special purpose arms are also made and the one shown in the photograph has a reach of 20in with a throat depth of 9in, giving easy access into parts normally difficult to reach. With these particular arms, a combined thickness of four 20 S.W.G. "Zintec" sheets is being satisfactorily welded.

The gun has a class H silicone insulated transformer, the secondary windings of which are bolted to silver-plated top and bottom barrels into which the electrode arms are fitted. Tip pressure is adjusted by turning a star wheel situated under the carrying handle, and tip pressures of 600 lb are achieved on the standard 8in reach arms. The gun is used in conjunction with the maker's Mark IV or "Velectronic" timer contactor units.

Research and Control Instruments, Ltd.

A new version of the Philips Automatic CO_2 welding equipment shown by Research and Control Instruments, Ltd., 207, Kings Cross Road, London, W.C.1, has a new and adaptable welding head and a closed circuit cooling system. One of the possible methods of applying this equipment shown is a set arranged for the continuous production of repeat straight runs. Another set is mounted on a conventional 14ft welding boom having an arc height of 8ft 9in for the welding of pressure vessels or similar items, using standard rotators. From among the products for which Philips automatic CO_2 welding process is being used is shown one production sample of a tube with a welded flange.

Prominence is given on the stand to the firm's recently introduced contact electrodes for hard-surfacing, and to the "Philips C16," a zircon-iron powder contact electrode for difficult (low alloy) steels.

The latest stud welding equipment operates on either a.c. or d.c. from any adequate conventional welding source. With this process any screw or stud made from mild, low alloy, or stainless steel can be fixed in any desired position. Specially prepared screws or studs are not necessary, the whole welding process being initiated and controlled by a welding cartridge which is placed round the weld piece in contact with the base to which it is to be welded. Any diameter of weld-piece from $\frac{3}{16}$in to $\frac{5}{8}$in can be accommodated by changing the work-holder and fitting the correct size cartridge.

The principle of Philips marine engine indicating is shown by a model with controls which visitors can vary to simulate the normal engine and propeller movements of a ship; the variations in engine quantities are simultaneously indicated and recorded on a standard panel identical with that fitted aboard ship. This equipment presents and records, continuously and instantaneously, all the essential data of a ship's operating efficiency. Some of the variables that can be kept under survey are engine efficiency, fuel consumption, effective power transmitted, shaft speed, shaft torque, propeller thrust, temperatures and cooling water consumption. All information is brought to one central point, and the most comprehensive installation requires only 24 cubic feet of space.

Two Mueller industrial X-ray portable tank units shown are claimed to give fully consistent radiographs through automatic application of the voltage to the tube. The desired kV value and the time of exposure are pre-selected and the operation follows completely automatically when the exposure button is pressed, the voltage being applied in two sequential stages. A very good power/weight ratio is claimed. One model shown weighs 55 lb, for a maximum output of 140kV 5mA, with 1·2mm focal spot. Another model which weighs 84 lb has a maximum output of 200kV 5mA, with 1·6mm focal spot. A control box weighing 55 lb is suitable for either unit, and this control box incorporates both voltage and thermal overload protection and a blinker device for the connection of a high tension warning lamp.

Bristol Aeroplane Plastics, Ltd.

A form of pipe made from wound glass fibre impregnated with thermo-setting resin and a reinforced plastics chemical storage tank are the principal exhibits of Bristol Aeroplane Plastics, Ltd., Filton House, Bristol. The "Epoch" pipe, as it is known, is specially intended for use in the chemical, oil, nuclear energy, gas and other industries where corrosive liquids and gases have to be handled. Its corrosion resistance properties are imparted by the use in its manufacture of high-strength glass and acrylic fibre and thermosetting Epoxine resin. In the process of manufacture the resin impregnated glass fibre rovings are wound on to pre-heated mandrels which impart a mirror-smooth pipe bore. Test have shown that the pipes under service conditions, in addition to resisting corrosion, heat and abrasion, perform well under elevated and sub-zero temperatures. They are stated to be as strong as steel pressure pipes, one quarter the weight and highly flexible.

These pipes are made in sizes from 4in to 15¼in bore and in lengths up to 20ft. A standard range of bends, tees and other fittings are available with the pipes, which can be provided with either flanged or bonded joints. The plastics tanks were originally developed for the United Kingdom Atomic Energy Research Establishment at Harwell, where a number have been installed to handle radioactive effluent. For this application reinforced plastics made from specially developed resins were chosen as it was essential to avoid deterioration of the material or structure.

Allspeeds, Ltd.

The familiar "Kopp" variators made by Allspeeds, Ltd., Accrington, are designed to transmit constant power and give infinitely variable speeds between a minimum of one-third and a maximum of three times the input speed. These units, made in different sizes to cover from $^1/_{33}$ h.p. to 15 h.p., are available either with free shaft ends or flange-mounted to motors and reduction gears. A new point in the design of the variators, introduced earlier this year, is the use of angular contact bearings in the shaft assemblies on all sizes, which has been affected without changing the outside dimensions of the units. Previously each of the co-axial shaft assemblies was fitted with two ball journal bearings flanking a single thrust race. All the new shaft assemblies are fitted with one cylindrical contact bearing and, in the case of units up to 1½ h.p., a single angular contact bearing. For the larger power variators matched pairs of angular contact bearings are used. As a result of this development there has been an improvement in overall efficiency, as well as a considerable increase in the maximum permitted running speeds.

The space saved by the elimination of the single thrust race can be used to accommodate, on the shaft, a small oil pump. This pump enables the variator to be adapted for almost universal mounting; previously, units for vertical mounting required an additional sump and external oil circulating system.

An electronic test rig shown is used for determining the constancy of the ratio of the input and output speeds and demonstrates the sensitivity, responsiveness and accuracy of the variator's controls. The test rig incorporates a J. Langham Thompson digital counter which shows the ratio as illuminated numerals on an indicating panel. A Mark III speed corrector unit exhibited has been developed to maintain a constant linear speed when a length of ciné film is wound from one reel to another, and the principle can be applied on most winding applications requiring constant linear speed.

The Bergius Company, Ltd.

Displayed by the Bergius Company, Ltd., are six Kelvin engines, including two of the "T" range, namely a T3 and a T8. These engines, which have electric starting, have a bore of 6½in and a stroke of 7½in and develop 30 h.p. per cylinder at 1000 r.p.m. Both have oil-operated reverse reduction gears having ratios of 2, 2½ or 3½ to 1 to give propeller shaft speeds of 500, 400 or 300 r.p.m. The three-cylinder engine develops 90 s.h.p. and weighs 2 tons and the eight-cylinder unit develops 240 s.h.p. and weighs 3·5 tons. Examples of lower-powered engines include a J3 cold-starting unit of 33 b.h.p. at 1000 r.p.m. and having three cylinders of 4¼ in bore by 6⅜in stroke, and a P2R engine having two cylinders of 3½in bore and 4in stroke and rated to develop 10 h.p. at 1500 r.p.m. through a 2 to 1 reduction gear. A 10kW alternator powered by a P4 engine is on view and also a two-cylinder Kelvin Ricardo Mark E2 paraffin engine of 7½ h.p. at 1150 r.p.m., complete with reverse gear.

(*To be continued*)

THE ENGINEER

Technical Contributors Section

MAY, 1961

100kW "Jason" Reactor

A. C. HUGHES. M.Sc., A.M.I.Mech.E., C. SANDERS, A.M.I.Mech.E., M. G. TENNET, B.Sc.*

Since the first "Jason" reactor was built at Langley, near Slough, in 1959, a series of reactors based on this design has been developed to suit the varying requirements of Universities and other research establishments. The different versions show considerable variations in experimental facilities and in some cases the power level has been increased from 10kW to 100kW. The problems which are encountered in making this ten-fold increase in power arise not only in connection with the removal of the extra heat produced but also with a number of side effects which, although negligible at 10kW, become significant at 100kW. This article examines these effects and describes the steps taken, where necessary, to prevent them from becoming troublesome. Particular attention is paid to the safety of the system and a programme of work carried out on the Langley "Jason," which throws considerable light on the behaviour of a 100kW reactor under severe fault conditions is described here for the first time.

The Standard 10kW Reactor

THIS reactor is similar to the "Argonaut" reactor designed and operated by Argonne National Laboratories[1]. A prototype version of the standard "Jason" is operating at Langley and a fully engineered version is now being operated by the Reactor Centrum Nederland. The reactor is capable of being operated continuously at 10kW, whereas "Argonaut" was intended for intermittent operation, and numerous changes were made in order to meet the more intensive requirements. The reactor has been described elsewhere[2,3,4] and it is only necessary to outline the more important developments :

(*a*) The core components were completely redesigned so that changes in core configuration could be made quickly and easily.

(*b*) The fuel handling equipment was developed to cope with more active fuel.

(*c*) The control rod mechanisms, which are buried in the reflector, were shielded to protect them from damage and activation.

(*d*) The density of the bulk shielding was increased.

At the same time the many attractive features of "Argonaut" were retained : the annular core with a large experimental volume in the region of maximum flux and with the facility for the construction of alternative fuel configurations ; the large external graphite envelope of considerable dimensions in which the flux gradient is much less than that associated with water immersed systems and which provides large experimental faces capable of being exploited for bulk irradiation work. The compact control system was originally designed to allow large experiments to be constructed above the core and this facility has recently been improved by the introduction of a lead rotating plug which adequately protects against shut-down γ radiation while freely permitting the passage of neutrons.

Developments from the Standard Reactor

These developments can be divided into two categories :

1. Changes in experimental facilities.
2. Increases in power.

The first category really stems from the differing requirements of users and potential users. Probably the best example is the "Nestor" reactor[5] which utilises the basic "Jason" unit but which provides a completely different experimental layout. For this reactor the U.K.A.E.A. has designed four large cave areas with a system of isolating shutters to cope with a programme involving large numbers of reactor lattice experiments.

An increase in power is a natural development since it increases the scope of the reactor, bringing new experiments within its range, e.g. neutron diffraction measurements, and it increases the accuracy with which certain other experiments may be performed. A power increase need not be accompanied by changes in experimental facilities but clearly, if full advantage is to be taken of the increased capabilities, some changes are almost inevitable.

The 100kW Reactor

A tenfold increase in power is not to be undertaken lightly since there are some effects which are negligible in a 10kW reactor which might become inconvenient or even troublesome when increased by a factor of ten :

1. Wigner Energy storage in the graphite.
2. Activation of core components with consequent restrictions on access.
3. Radiation damage, especially to electrical components within the core.
4. Circuit activity, especially the O^{16} (n,p) N^{16} reaction in the cooling water.
5. Activation of argon in the air above the core and the consequences of leakage into the reactor building.
6. Increase in the fission product concentration and the possible repercussions on siting.
7. Decay heating and the possible rise in the fuel plate temperature when the cooling water is dumped.
8. The consequences of pump failure at higher ratings.

These problems are additional to the normal development of the reactor system, i.e., (i) Higher flow rate in the cooling circuit. (ii) Increased shield thickness (or shield density). (iii) Heavier fuel element flask. (iv) Extended instrumentation range.

Whilst all of the problems listed above can be designed out of the system there is a simple arrangement which removes a number of the problems automatically. This is to produce a reactor capable of being operated for very long periods at 100kW but whose programme is arranged such that the average power, measured over a period of months, does not exceed 10kW. This arrangement would avoid undue Wigner Energy storage, long term activation of components and irradiation damage. If, as a further arbitrary restriction, the maximum duration of a run at 100kW is limited to 48 hours then the iodine fission product concentration would only just exceed the 10kW equilibrium value, and since this is the main factor in site assessment then siting and building conditions need not

*Hawker Siddeley Nuclear Power Company, Ltd.

Technical Contributors Section (*continued*)

differ from those for a 10kW reactor. Another attraction of this scheme is that the standard 10kW fuel handling equipment could be utilised. Since, on the basis of a five-day week, the reactor could be operated for 3½ hours a day at 100kW, or for longer periods at less frequent intervals, this arrangement is likely to suit most programmes especially those of Universities. Since this is also the cheapest way in which to achieve 100kW this scheme has already been adopted for some future applications. The remainder of this article is devoted to the description of a reactor designed along these lines.

General Description.—A typical arrangement of the 100kW reactor is shown in Figs. 1 and 2. These show the reactor arranged to provide a large number of in-pile irradiation facilities.* The shield tank, which is a standard feature of the 10kW reactor, has been replaced by a thermal column which is, however, removable and which can be replaced either by a shield tank or by some other bulky experiments. The reactor is therefore provided with two thermal columns, each with twelve stringers 4in by 4in and one stringer 12in by 4in. One of the stringers in the static thermal column penetrates to the core tank. The number of beam holes has been increased and five through holes are provided, each passing quite close to the reactor core tank. The thermal neutron flux in this region is about 10^{12}n/cm² sec. at 100kW.

The thermal column stringers and the beam hole stringers and plugs have been designed so that they can be removed through the fuel handling flask when the reactor is at standby or at low power.

A number of pneumatic transfer tubes are included to provide quick and convenient movement of experimental samples.

Core.—Details of the core are shown in Fig. 4. As with the 10kW reactor the fuel region is formed by two concentric tanks which provide an annulus 2ft internal diameter and 3ft external diameter. Graphite wedges, which are rigidly clamped, divide the annulus into 24 compartments, each approximately 3in by 6in in cross-section. Each compartment is capable of receiving either two fuel elements or one fuel element and a graphite block. These graphite blocks have the same external dimensions as a fuel element and blocks and elements are interchangeable. It is thus possible to assemble a number of useful configurations, notably the single slab when two elements are loaded in each compartment over six adjacent compartments, and the annular core when the inner position in every compartment receives a fuel element. In both cases the spare positions are filled with graphite blocks. The annular core (critical mass 4·2 kg U235) provides great symmetry, with the thermal flux peaking to $1{\cdot}5\times10^{12}$n/cm² sec. in the centre of the graphite reflector which fills the inner tank. The slab core (critical mass 2 kg U235) gives slightly higher fluxes in the region of the core but, of course, the distribution is not so favourable. The thermal and fast fluxes associated with the slab core are shown in Fig. 3 and the fluxes at the experimental facilities are given in Table I.

* This arrangement was suggested by the Universities of Manchester and Liverpool.

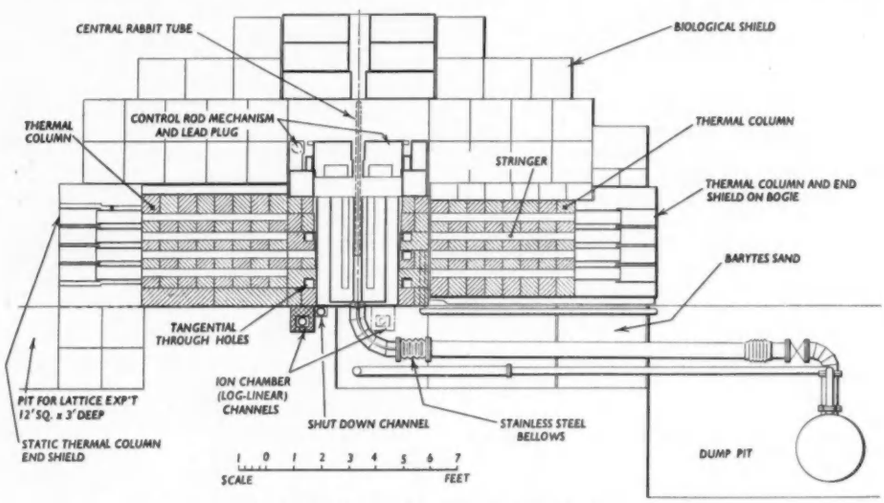

Fig. 1—Vertical section through thermal columns

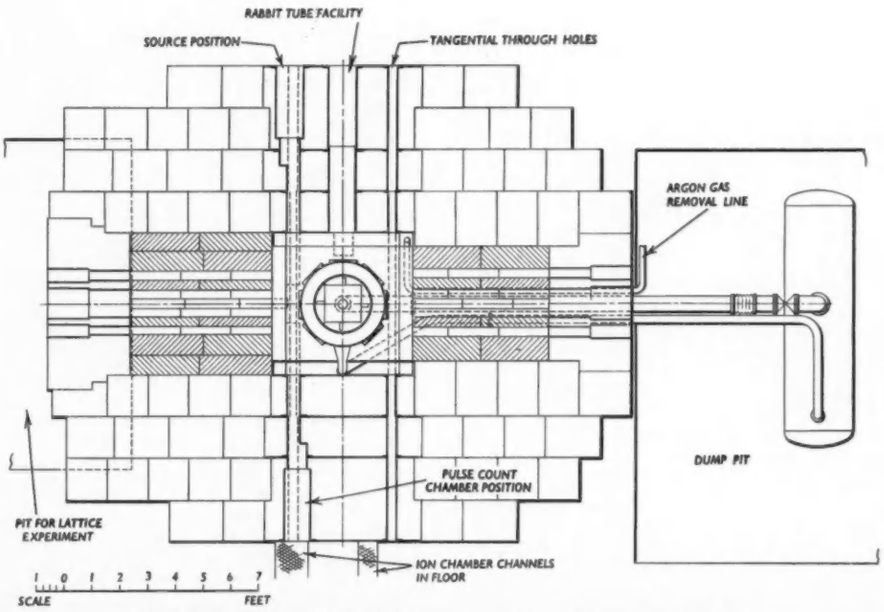

Fig. 2—Section at mid-height of core. For details of dump pit see Fig. 8

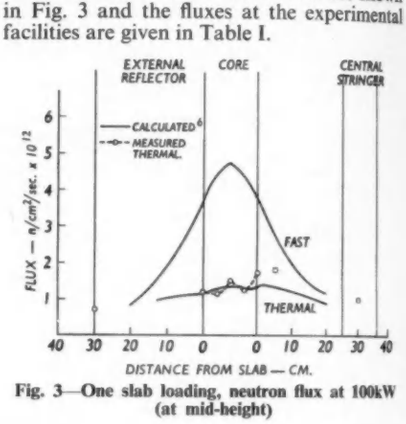

Fig. 3—One slab loading, neutron flux at 100kW (at mid-height)

TABLE I.—*Thermal Fluxes at Experimental Facilities*

Position	Core arrangement		
	Slab near	Slab remote	Annulus *
Beam holes (mid-position)	$1{\cdot}5\times10^{12}$	10^{11}	8×10^{11}
Internal thermal column (centre)	1×10^{12}		$1{\cdot}5\times10^{12}$
Thermal column/reflector interfaces	7×10^{11}	5×10^{10}	4×10^{11}
Lead plug (top face)	10^{10}		10^{10}

* The fluxes for another arrangement, the two slab core, are similar to those quoted for the annulus.

The method of locating fuel boxes has been chosen to combine rigidity during operation with free movement during fuel handling. The dome on the bottom of a fuel element (see Fig. 5) locates in a shallow cone in a lattice plate and pins at the top of the fuel box (which are actually extensions of the handling bar) locate in shallow slots in the top of the wedges. Since there is liberal clearance between the sides of the fuel box and the rest of the structure an element moves freely during fuel handling and is only closely guided when it is within ½in of its rest position. This system has proved entirely satisfactory in operation and the core reactivity is not disturbed when elements are removed and subsequently replaced. Furthermore since clearances are adequate the only tightly toleranced dimensions are those over the pins on the top of the box and on the slots in the wedges. Since accuracy on these small components is easily obtained it is possible to position fuel boxes to within 0·020in without invoking difficult manufacturing problems.

Cooling Requirements.—The reactor is cooled and moderated by light water which passes up between the two core tanks and through the fuel boxes. The major difference between the 10kW and 100kW reactor occurs in this cooling circuit because of the greatly increased flow rate (45 g.p.m.) required to maintain modest temperatures in the more highly rated system.

There are three important safety aspects associated with the coolant flow :

1. When the water level is being raised in the core during the daily start-up procedure, reactivity is being added to the system. To minimise the effects of an error in core loading it is desirable to restrict the rate of change of reactivity. This is achieved simply by controlling the rate at which water is pumped into the core at this stage. Since the desired rate is less than that required for adequate cooling at full power two pumps have been installed, the high-capacity pump being interlocked in such a way that it can only be operated when the core tank is full.

2. When the reactor is scrammed from full power the coolant is suddenly removed and it is necessary to ensure that the decay heat is removed without the fuel elements rising to undesirable temperatures. It has been established by calculation that if the fuel plates are brazed together at the edges (a normal arrangement for " Dido "-type boxes) then the temperature rise is modest even if it is assumed that there is zero air convection and that the only heat sink is the internal reflector.

3. If the pump fails whilst the reactor is operating at high power then the reactor may continue at power until corrective action is taken or until the temperature rise reduces reactivity. Since it is essential to establish that this latter process should not lead to excessive fuel temperatures a number of experiments were conducted on the 10kW Langley Reactor. The results are important and are given below.

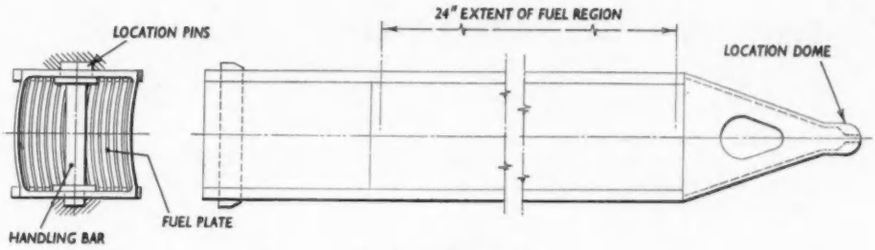

Fig. 5—Fuel element

Experiments on the Langley " Jason "

The experiments described below were carried out on the 10kW Langley " Jason " and were designed to investigate the behaviour of " Jason "-type reactors following a coolant circulation failure at 100kW power level. For the purposes of this experiment the Nuclear Site Licence was altered to permit operation between 10kW and 100kW for a total period of two hours, with a time limit of 20 minutes on any one run. The experiments were carried out on a single slab core configuration, with the normal 10kW cooling system giving a maximum primary coolant flow rate of 4·4 g.p.m., compared with the design figure for the proposed 100kW version of 45 g.p.m. This relatively low flow rate resulted in higher than normal temperature rises over the core.

The experiments were first carried out at 50kW. Pump failure was simulated by stopping the pump whilst the reactor was at steady power, and the subsequent power level and temperature of the core were observed. In the first run the control rod setting was not altered after stopping the pump, and in the second all the available excess reactivity (0·43 per cent for a cold core) was added in an attempt to keep the power level constant. The purpose of this latter procedure was to anticipate the action of an operator who might not realise that the pump had stopped, and would try to keep the power level constant. As these two runs gave very moderate temperature rises they were repeated at 100kW, and again the maximum temperatures were still very low.

The fuel plate temperatures were measured by means of thermocouples peened into the cladding at fuel mid height. Four thermocouples were fitted on two plates, in a central box. In general there was no significant temperature difference between the two plates, one of which was near the centre of the core, and one near the outside. The water temperature was measured by means of two thermocouples level with the top of the fuel box, about 4in above the fuel itself. One thermocouple was positioned over a central fuel box, and one over an outer box. The water outlet temperature was measured by means of a resistance thermometer against the outer tank, level with the top of the reflector.

The reactor power was raised from 10kW to 50kW on a doubling time of about 40 secs. It was intended to stop the pump when the control rod setting indicated that the reactivity in the core, and hence the mean core temperature, corresponded to the design temperature for the 100kW version. However, because of the low flow rate and consequently high temperature rise in the core, this did not

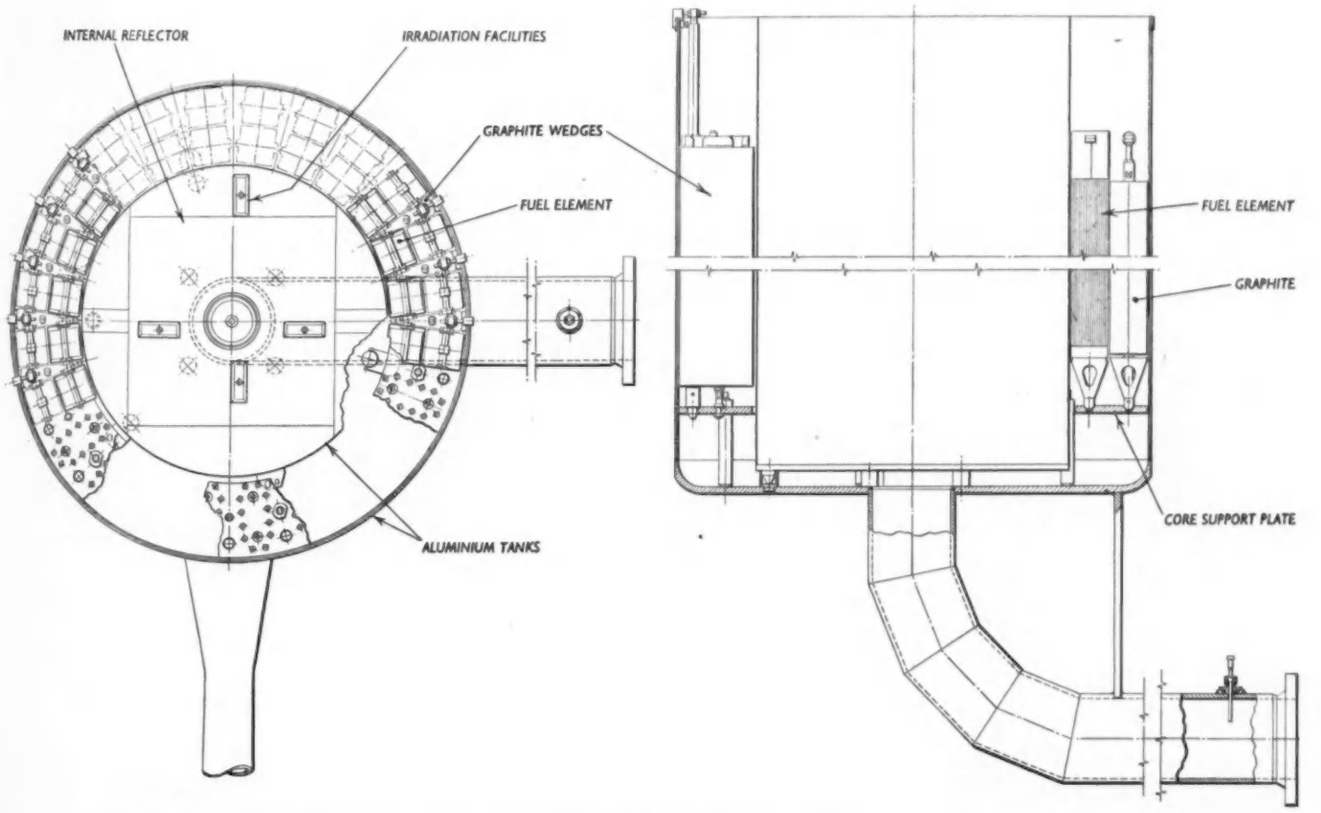

Fig. 4—Core assembly

Technical Contributors Section (*continued*)

prove feasible. The most convenient place to stop the pump was when the control rod setting indicated an excess reactivity corresponding to a mean temperature some five degrees higher than the design temperature. This means that the temperature after the pump was stopped was a little higher than would be obtained after a pump failure on a 100kW version of the reactor. After the pump had been switched off and the appropriate valve closed to prevent water running back through the pump, the subsequent temperatures and power were noted, whilst the control rod setting remained unchanged. The procedure was then repeated, but this time the whole of the available excess reactivity was added to the core after the pump was stopped in an attempt to keep the power constant. The above experiments were then repeated at a power of 100kW. The results of the final 100kW run are shown in Fig. 6.

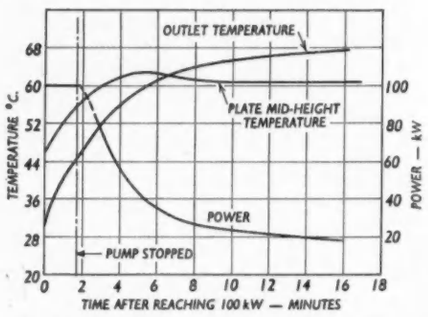

Fig. 6—Simulating pump failure at 100kW, run II

In all four runs the increase in core temperature following the pump stoppage rapidly introduced enough negative reactivity to shut the system down. In some cases the length of the run was limited by the licence restrictions, and in others by water leaking through the dump valve and shutting the system down on the " water level low " trip. In the first run at 100kW the power level settled out at about 10kW, with a steady coolant outlet temperature of 52 deg. Cent. In run II at 100kW (Fig. 6) when all the available excess reactivity had been added to the system (0·43 per cent for a cold core), the power level settled out below 20kW, with the outlet temperature approaching 70 deg. Cent.

It can be seen that, after a few minutes at 100kW, the top reflector temperature rose above that at fuel plate mid-height because of the movement of the hotter water to the top of the tank. The temperature of this water at the top of the reflector had little effect on the reactivity of the system which was determined mainly by the temperature of the water in the fuel region. Using a previous temperature coefficient measurement to calculate the mean temperature of the core from the amount of excess reactivity absorbed, gave a result which was always within a few degrees of the measured plate mid-height temperature.

This series of experiments has shown that there is no hazard associated with coolant circulation failure at 100kW, even if the operator does not notice the failure and adds all the available excess reactivity in an attempt to keep the power level constant. In all cases the negative reactivity introduced by the rise in core temperature rapidly shuts the system down whilst the water and fuel temperatures are still relatively low. As a result of these measurements it appears that trips associated with primary coolant flow rate and temperature will not be necessary on a 100kW version of the reactor.

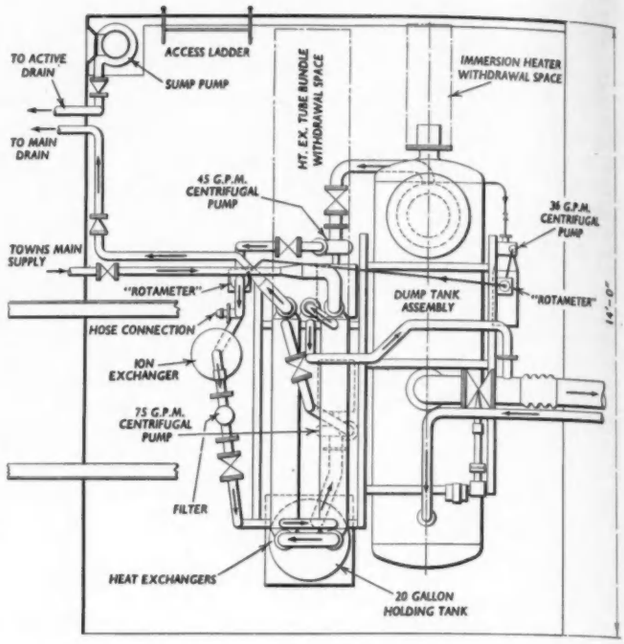

Fig. 8—Plan view showing arrangement of 100kW " Jason " dump pit

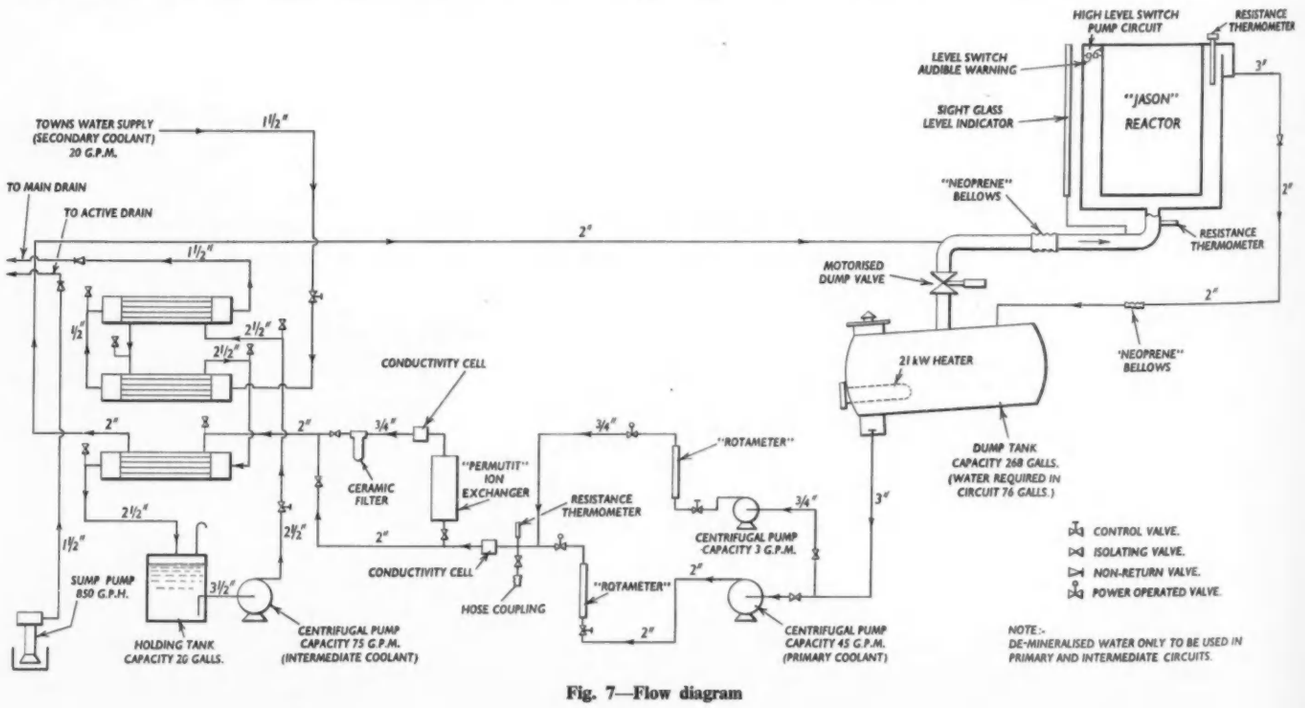

Fig. 7—Flow diagram

Details of the Cooling Circuit on the 100kW Design

The primary circuit is self-contained and includes a dump tank of volume 270 gallons which holds the total circuit capacity. Light water is pumped around the circuit at a rate of 3 gallons per minute during filling and 45 gallons per minute during operation. Initial charge and make-up is de-ionised water and a resin ion exchange column is included in a by-pass circuit to maintain purity. The flow diagram (Fig. 7) shows that, in addition to the primary circuit, there is an intermediate or secondary circuit and a separate mains water supply which forms a tertiary circuit. This arrangement provides a double barrier between the reactor water and the water which passes to the drains and thus avoids the necessity for monitoring the rejected water.

Since the primary water is very pure, long lived activity is insignificant. The only way in which the tertiary coolant can become active is if the following events occur.

1. Failure of fuel element cladding and subsequent release of radioactivity into the primary circuit.
2. Leakage in the primary/secondary heat exchanger.
3. Leakage in the secondary/tertiary heat exchanger.

The quantity of water in the secondary circuit can be observed and long-term leaks in the circuits would be noticed. Thus the rejected water can only become active in the unlikely event of three failures occurring simultaneously.

Table II.—*Flow Rate and Temperature at 100kW*

Circuit	Flow rate g.p.m.	Inlet temp. deg. Fah.	Outlet temp. deg. Fah.
Primary...	45	100	114
Secondary	75	92	84
Tertiary (mains supply) ...	20	60	—

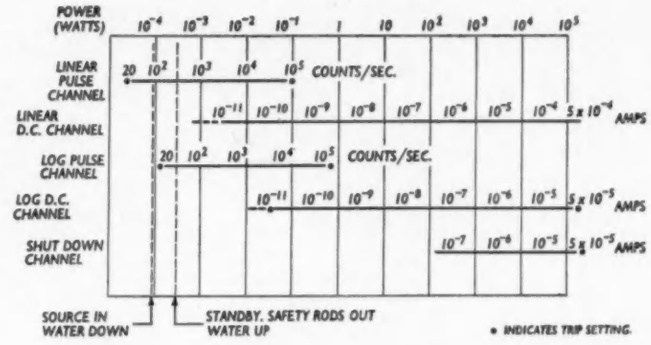

Fig. 10—Flux coverage of channels

The cooling units and pipework external to the reactor are located in a pit at one side of the reactor. In order to reduce site work to a minimum the whole of this equipment is mounted on a frame which is merely connected up to the reactor during the construction stage. Not only does this reduce construction costs but it allows the cooling system to be checked as a complete unit at the works prior to despatch. The arrangement of the equipment in the dump pit is shown in Fig. 8.

Activation of Primary Water

The purity of the water is such that the activity due to impurities is small compared with the short-lived activity of the water itself. The most important source of activity of the water is the seven-second N^{16} produced by the reaction O^{16} (n,p) N^{16}. In the standard 10kW reactor the time for the water to travel from the core region to the exposed part of the dump line and tank is long enough for most of the activity to decay. For the 100kW case, not only is the rate of production of N^{16} ten times higher, but the increased circulation rate means that a higher proportion of the initial activity will reach the dump pit. The (n,p) reaction has a threshold at about 10 MeV and the distribution of flux with energy above the threshold is not known accurately. However, even assumptions that are expected to give an upper limit, yield a dose rate above the dump tank of only 10 millirem per hour and since this is likely to be a considerable overestimate it will not be necessary to shield the dump unit. Immediately following a scram from 100kW the dose rate above the unshielded dump pit rises rapidly and then decays away with a seven-second half life, giving an integrated dose of, at most, a few millirems.

Production of Active Argon

The small amount of argon present in air becomes active when irradiated by thermal neutrons. Some of the active argon might leak out from the air spaces near the core into the reactor building. If the maximum possible leakage rate of argon is assumed the contribution to the activity level in the reactor building would be of the order of 10 millirem per hour. It is expected that in practice, because the leakage rate will be lower than that assumed, the figure will be much less than this, perhaps even an order of magnitude lower. However it is proposed to exhaust the space above the core at a rate of 150 cubic feet per minute so that the leakage rate into the building will be insignificant.

Controls Rods

The reactor is controlled by cadmium blades which move in slots in the reflector just outside the core tanks. In earlier versions of the reactor the actuating mechanisms have been buried in the top layers of graphite thus forming a compact arrangement which could be exploited to provide a top irradiation facility for bulky experiments. One drawback of this arrangement is that the mechanisms can only be serviced after the fuel has been removed. To improve this situation the mechanisms have been relocated in the top shield box which has been deepened to receive them. Although not exclusive to the 100kW reactor this is likely to be the first application of this scheme. The arrangement is shown in Fig. 9.

The central lead plug which is designed to give protection against the shut down γ radiation can be rotated to position the fuel handling ports over the fuel positions. Since lead has a low neutron capture cross-section this unit provides a large neutron beam for experiments located above it. The control rod mechanisms are buried in the adjacent box to avoid interference with the fuel handling equipment or with the top experiments.

Because the reactor operates at an average of 10kW the burn-up and poison build-up is still small and the area of the control blades will be the same as for the standard 10kW

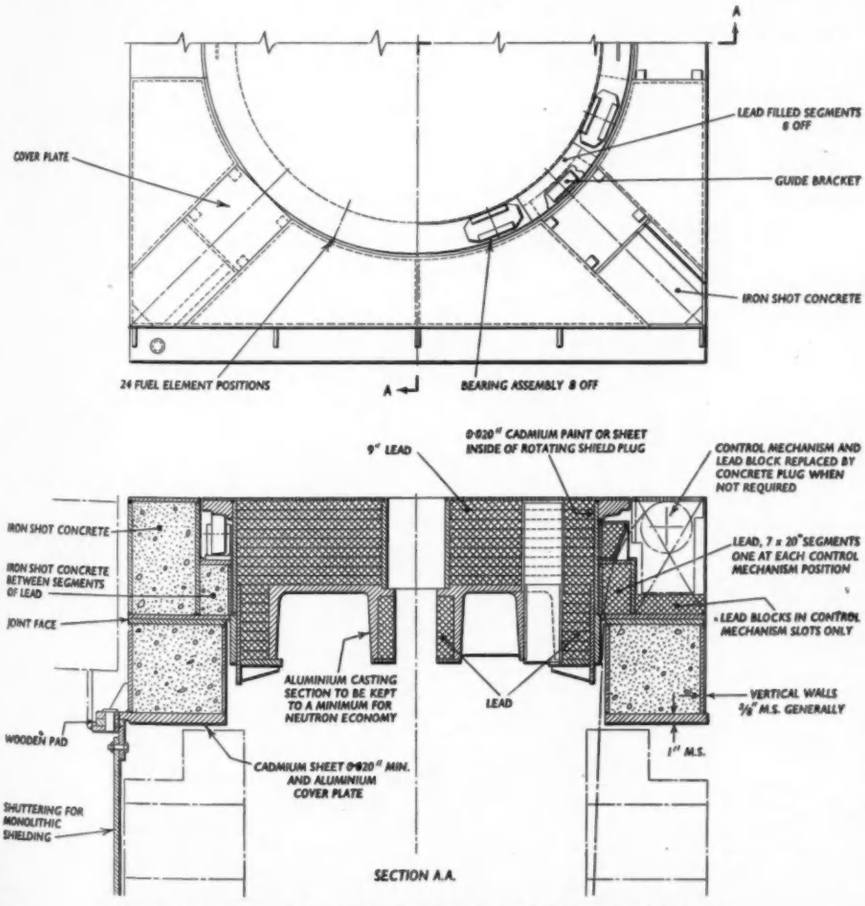
A
LEAD FILLED SEGMENTS 8 OFF
COVER PLATE
GUIDE BRACKET
IRON SHOT CONCRETE
24 FUEL ELEMENT POSITIONS
A
BEARING ASSEMBLY 8 OFF
9" LEAD
0·020" CADMIUM PAINT OR SHEET INSIDE OF ROTATING SHIELD PLUG
CONTROL MECHANISM AND LEAD BLOCK REPLACED BY CONCRETE PLUG WHEN NOT REQUIRED
IRON SHOT CONCRETE
IRON SHOT CONCRETE BETWEEN SEGMENTS OF LEAD
JOINT FACE
LEAD, 7 x 20" SEGMENTS ONE AT EACH CONTROL MECHANISM POSITION
• LEAD BLOCKS IN CONTROL MECHANISM SLOTS ONLY
ALUMINIUM CASTING SECTION TO BE KEPT TO A MINIMUM FOR NEUTRON ECONOMY
LEAD
VERTICAL WALLS 5/8" M.S. GENERALLY
WOODEN PAD
1" M.S.
CADMIUM SHEET 0·020" MIN. AND ALUMINIUM COVER PLATE
SHUTTERING FOR MONOLITHIC SHIELDING
SECTION A.A.

Fig. 9—Arrangement of control mechanisms in top shield box and lead plug

Technical Contributors Section (*continued*)

reactor. These blades are now larger than were originally fitted to earlier versions because the reactivity value on earlier models, although sufficient from the point of view of safety, was such that with the annular core it was not possible to provide for really coarse control. In order to avoid increasing the worth with the slab core, which has always been satisfactory, the control blades have been moved around the tank away from the slab position. With this arrangement convenient values are obtained whatever the core configuration.

Nucleonic Instrumentation

Five channels are provided to measure the neutron fluxes. They are :

1. A linear pulse channel consisting of a chamber connected to a pulse amplifier and a linear ratemeter covering the range 0–10 to 0–10^5 counts per second. Trip circuits operate if the signal input is less than 5 per cent or greater than 90 per cent at the full scale on the range selected.

2. A linear d.c. channel consisting of a gamma-compensated boron ionisation chamber feeding a multirange d.c. current amplifier which gives an effective coverage between 10^{-11}A to 10^{-4}A. Trip circuits operate if the input is less than 5 per cent or greater than 90 per cent full scale reading on the range selected.

3. A logarithmic pulse channel consisting of a fission counter which operates an amplifier and a logarithmic ratemeter with a coverage between 10 and 10^5 counts per second. A reactor period meter operates from the log-count-rate signal. Trip circuits operate if the count rate is below 20 counts per second and above 10^5 counts per second and a period trip is included.

4. Logarithmic d.c. channel. Similar to channel 2 but feeding a logarithmic scale and a reactor period meter. The range of the amplifier is 5×10^{-12} to 5×10^{-5}A. Low- and high-level trips and a period trip are provided.

5. A shut down channel employing an uncompensated ionisation chamber and a fail safe trip amplifier provides a reactor trip adjustable between 1 per cent and 200 per cent of full power.

Coverage of Neutron Flux Channels.—The flux coverage is shown in the chart, Fig. 10. The principle is to have both a linear and a logarithmic channel effective from the standby state (safety rods and water up) to full power. The linear pulse channel is arranged to be effective from the source level (water out) to about 100mW. Change-over to the linear d.c. channel is normally made during the last decade while both linear channels are in their effective range. The d.c. log.channel becomes effective at about 100mW and so the log. pulse channel is arranged to provide sufficient overlap for safe transfer between the channels and extend the logarithmic coverage down to the standby power level. High level trips on the d.c. channels are always effective but the low trips are by-passed while the reactor is controlled from the pulse channel signals. On transferring to the d.c. channels the pulse channel high-level trips are by-passed to allow the counters to be withdrawn from the neutron flux.

Applications of the 100kW Reactor

University requirements can be met to a large extent by the flux available in the 10kW reactor, i.e., a flux of 10^{11}n/cm²sec. Nuclear engineering laboratories, whose main interest is in studying reactor behaviour and in using the reactor as a source of neutrons for lattice experiments, would be amply satisfied by a flux of this magnitude and indeed might be inconvenienced by the more powerful system. However, there is some work in which a ten-fold increase in flux is useful (for example activation analysis and isotope production) and some work where it is a necessity, for example solid-state physics. The 100kW reactor therefore appeals to chemists, physicists, biologists and medical workers and is likely to find favour where a reactor has to be shared amongst all the departments of a University.

The needs of such a variety of workers are likely to change from time to time. For this reason the shielding of the reactor is constructed of concrete blocks (a system already employed with great success on existing "Jason" reactors) which can be rearranged to suit the immediate needs of new experiments.

Acknowledgements

The authors acknowledge the contribution made by colleagues in the project and development departments and in the "Jason" operations team, particularly the substantial contribution by R. Bailey, M. A. Blaxill, T. R. Thompson and M. R. Williamson. They also acknowledge their debt to the staff of Argonne National Laboratory for their skilful realisation of the "Argonaut" concept and they are grateful for the help given by the U.K.A.E.A. Health and Safety Branch and the Ministry of Power in connection with the 100kW programme on the Langley "Jason."

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An Industrial Investigation of a Process for Tube Drawing

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The purpose of tube drawing is to improve the mechanical properties of the material and/or attain dimensional accuracy and good surface finish. The investigation described in this paper showed that the improvement in mechanical properties can be related to the amount of plastic straining by use of the true-stress true-strain curve of the material. For given final specifications of strength and diameter, it is possible to determine the specifications of tubes required prior to drawing and the amount of reduction and number of reductions to be carried out. The annealing process was found to be insensitive to furnace-temperature within a wide temperature range ; also it was established that annealing is fairly rapid and effective only during the initial part of the present cycle time, so that a shorter cycle may be adopted without adverse effect.

1. Introduction

THE investigation to be described was conducted in an attempt to find the effect of certain process variables on the resulting strength and material properties of steel tubes. The variables concerned are cold drawing and annealing, and part of the object of the investigation was to be able to specify the optimum drawing and annealing conditions required to give satisfactory material with minimum cost.

The material fed into the process is either in the form of seamless tubes produced from the Mannesmann-Pilger mill processes, or seam-welded tubes, and the latter were used for the present investigation. Drawing is applied to these tubes for two purposes : (i) to achieve dimensional accuracy and good surface finish, (ii) to improve the mechanical properties of the material. Annealing or normalising of the tubes is necessary before drawing, to ensure that they are all in the same ductile condition and suitable for drawing ; it may also be necessary after drawing, in order to restore ductility to comply with customers' requirements. The optimisation of these two process variables on an economic basis involves a lengthy study, in which detailed parameters such as lubrication, drawing reduction and number of reductions, drawing speed, annealing temperature, annealing time in the furnace, and time to cool from annealing temperature, all play a part. The present report was concerned with a relatively small part of such an investigation, namely by tensile and hardness tests of a number of tube samples before and after treatment, to find the effects of tube drawing (without internal mandrel) and annealing under industrial conditions.

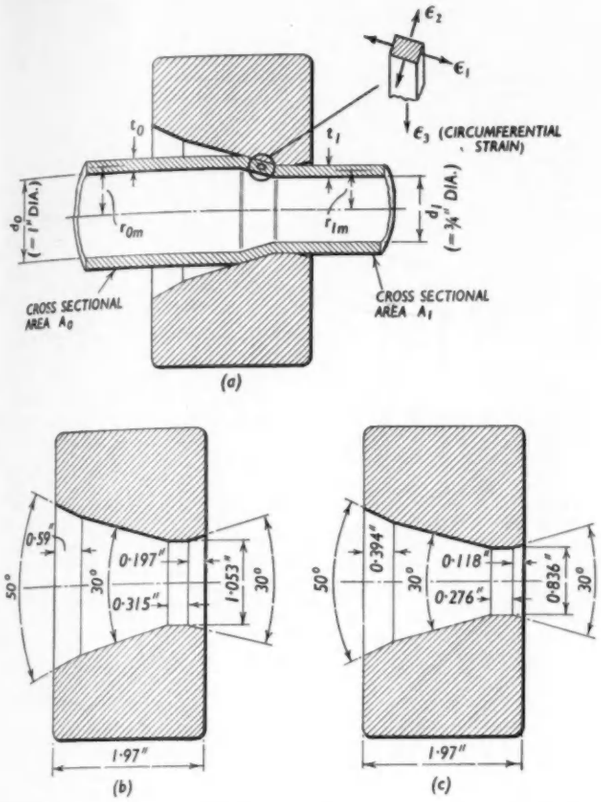
2. The Industrial Process

In what follows, the dimension quoted refers to the inside diameter of the tube. Initially 1in diameter seam welded tubes were annealed and straightened by reeling (hot). After this treatment they were cooled in air on their way to the tube drawing machine. At this machine, one end of the tube was heated and forged into a tang suitable for gripping in the "dog" of the draw bench. The tubes were then dipped into a bath of lubricating soap, after which they were drawn through a die as illustrated diagrammatically in Fig. 1(*a*). Figs. 1(*b*) and 1(*c*) show the dimensions of actual dies used, from which tubes of internal diameters nominally $\frac{3}{4}$in and $\frac{1}{2}$in were produced by successive drawing.

3. Experimental Procedure

The material used was steel produced by the Siemens Martin process, to specification SAE 1010 (U.S.A.) and it was drawn at a speed of approximately 20ft per minute.

Annealing was carried out at temperatures of 600 deg., 625 deg., 650 deg., 675 deg., 700 deg. and 750 deg. Cent., the annealing



(*a*) Reduction of diameter from 1in to ¾in, showing symbols used.

(*b*) Die used for producing ¾in tube.

(*c*) Die used for producing ½in tube.

Fig. 1 — Tube drawing process

time being varied initially as follows: 20, 40, 60, 80 and 100 minutes. The procedure for annealing was that when the empty furnace reached the desired temperature, five tubes (each of length 14½ins:, inside diameter ½in) were put into the furnace, which immediately cooled off. The time of annealing was measured from the time at which the furnace again reached the desired temperature. The laboratory furnace used in these experiments had an automatic temperature control, which was effective in maintaining the desired temperature to within ±2 deg. Cent. Every twenty minutes one of the tubes was taken out and allowed to cool in air, thus providing the required set of five results (up to 100 minutes). Tensile and hardness tests were carried out on these tubes to ascertain the effectiveness of the annealing treatment. As it was found that for times of soaking longer than twenty minutes there was little change in the material properties, it was decided to carry out further tests to establish the effectiveness of annealing during the first twenty minutes. These tests were carried out at a temperature of 650 deg. Cent., for periods of 3, 6, 9, 12, 15 and 18 minutes.

Hardness tests were carried out on a Rockwell tester, using 10 kg initial load and 150 kg minimum load. A minimum of four stations round the circumference of any tube were tested and a mean value taken. These tests were conducted on ten tubes just before drawing and on the same ten after drawing.

Tensile tests were carried out on an Amsler universal testing machine, elongation being measured by conventional laboratory extensometers over a gauge length of 8in until the commencement of yielding. After this point the extension was measured using a steel rule and a pair of dividers, to an accuracy of ±0·02in. The initial cross-sectional area of the tube was calculated from the equation $A = W/\rho L$, W being the weight, ρ the density, and L the length of the tube. Steel "corks" were inserted into the ends of the tubes to prevent buckling during the tensile tests.

4. Results

Table I shows the results of tensile and hardness tests on tubes before and after drawing from 1in to ¾in inside diameter. In Table II are shown typical values of hardness variation round the circumference of a tube, both on its outer surface and its cross section. Tensile tests were made on two samples of the tubes before drawing, the ends being plugged to prevent collapse in the jaws of the testing machine. These tests were used to give the "master" stress-strain curve of the annealed material before drawing, the true strain at fracture being determined from the area reduction in the

TABLE I—*Comparison of Mechanical Properties Before and After Drawing from Nominally 1in to ¾in Inside Diameter*

Tube No.	1	2	3	4	5	6	7	8	9	10	Mean values
Reduction of area due to drawing, percentage	18·4	Not measured	18·8	19·0	18·2	18·7	19·0	18·0	18·1	Not measured	18·5
Rockwell Hardness :											
Before	55·3	60·3	58·0	65·0	64·0	58·5	67·5	64·0	65·0	59·0	61·7
After	82·0	80·6	84·0	86·6	82·0	79·0	84·0	82·3	87·0	83·0	83·0
Percentage increase	48·3	33·7	44·8	33·2	28·1	35·0	24·4	28·6	33·8	40·7	34·5
Ultimate tensile strength, tons per sq. in											
Before	22·7	22·9	25·6	25·0	25·7	23·4	25·4	24·4	25·7	24·7	24·6
After	31·8	Not measured	35·3	34·9	35·6	32·2	35·7	33·8	35·4	Not measured	34·3
Percentage increase	40·1	Not measured	37·9	39·6	38·5	37·6	40·6	38·5	37·7	Not measured	39·4
Percentage elongation (on 8in gauge length) :											
Before	30·0	30·0	26·5	28·0	30·5	29·0	26·8	29·0	28·0	27·0	28·5
After	9·1	Not measured	4·9	7·9	9·1	8·2	8·5	7·9	9·0	Not measured	8·1

TABLE III—*Tensile Test on Tube A1*

Nominal stress p, tons per sq. in	Percentage extension 10^2e	True stress $(\sigma = p(1+e)$ tons per sq. in	True strain $\varepsilon = ln(1+e)$
2·77	0·021	2·77	0·00021
5·55	0·045	5·55	0·00045
8·33	0·065	8·33	0·00065
11·1	0·0845	11·1	0·00085
13·6	0·110	13·6	0·00110
13·9	0·61	14·0	0·00582
16·7	3·11	17·2	0·03061
18·0	3·86	18·7	0·03776
19·4	5·61	20·5	0·05461
20·8	7·26	22·3	0·07014
22·2	9·86	24·4	0·09438
23·6	14·86	27·1	0·13851
24·2	31	33·4	0·27
(Conditions at maximum load)			
Not measured	192	Not measured	1·072
(Conditions at fracture (based on area reduction in the neck))			

Tensile Test on Tube B1

Nominal stress p, tons per sq. in	Percentage extension 10^2e	True stress $\sigma = p(1+e)$ tons per sq. in.	True strain $\varepsilon = ln(1+e)$
1·37	0·009	1·37	0·00009
2·74	0·019	2·74	0·00019
4·11	0·031	4·11	0·00031
5·49	0·041	5·49	0·00041
6·85	0·051	6·85	0·00051
8·25	0·0605	8·25	0·00061
9·6	0·0715	9·60	0·00072
11·0	0·0820	11·0	0·00082
12·36	0·0920	12·3	0·00092
13·72	0·1030	13·7	0·00103
15·1	1·6	15·3	0·01567
16·5	2·1	16·9	0·02075
17·86	2·85	18·4	0·02790
19·2	4·35	20·1	0·04256
20·6	6·1	21·9	0·05922
22·0	8·85	24·0	0·08506
23·3	14·10	26·6	0·13190
23·9	31	33·1	0·27
(Conditions at maximum load)			
Not measured	192	Not measured	1·072
(Conditions at fracture in the neck))			

TABLE II—*Variation in Hardness Around Circumference of Tubes Before and After Drawing (Rockwell Test)*

Station No.	Sample A1				Sample B1				Sample A2				Sample B2			
	One end		Other end		One end		Other end		One end		Other end		One end		Other end	
	Surface	Cross section	Surface	Cross section	Surface	Cross section	Surface	Cross section	Surface	Cross section	Surface	Cross section	Surface	Cross section	Surface	Cross section
1	36·5	34·5	37	35·5	38	32	37	36	54	58	56	58	56	53	55·5	56
2	37	34	39	43	35	35·5	34	38	55	60	56·5	51·5	56	54	55	57
3	37	34	38·5	37	38	39·5	44	37	55	56·5	55	56	55	57·5	57	56·5
4	38	36	38·5	28	39	34·5	39	33	58	56	56	56	52·5	57·5	57·5	57·5
5	38	36	39	30	34	29·5	38	35	55·5	58	53	57	52·5	59	55	57
6	40	33	40·5	34·5	39	35	38	41·5	56·5	56·5	53·5	56·5	51	57	51·5	54
7	38	36	37·5	30	38	31·5	38·5	38	59	57·5	54	54	57	57·5	54·5	57·5
8	38	36	39	31	34	34	40	34	60	60	52·5	55·5	53	56	54·5	59
	Before drawing								After drawing							

Technical Contributors Section (*continued*)

neck. This area was measured on each end of the fractured samples by using a projection microscope, tracing the profile, and measuring the traced area with a planimeter. No correction factor was applied to allow for the non-uniform state of stress in the neck of the tensile specimens. The two samples were designated A1 and B1 and the results of these tests are given in Table III and Fig. 2. Two samples of drawn tubes, designated A2 and B2, were also tested, the results being as shown in Table IV and superimposed on Fig. 2.

TABLE IV—*Tensile Test on Tube A2*

Nominal stress p, tons per sq. in	Percentage extension 10^2e	True stress $\sigma=p\ (1+e)$ tons per sq. in	True strain $\varepsilon=ln\ (1+e)$
1·61	0·0135	1·61	0·000135
3·22	0·0280	3·22	0·000280
4·84	0·0415	4·84	0·000415
6·45	0·0540	6·45	0·000540
8·06	0·0665	8·06	0·000665
9·68	0·0775	9·68	0·000775
11·3	0·0905	11·3	0·000905
12·9	0·1025	12·9	0·001025
14·53	0·1135	14·6	0·001135
16·13	0·1255	16·2	0·001255
19·37	0·1510	19·4	0·001510
22·6	0·1760	22·6	0·001760
24·2	0·1960	24·2	0·001960
25·8	0·2060	25·8	0·002060
27·5	0·2270	27·6	0·00227
29·1	0·2490	29·2	0·00249
30·7	0·2795	30·8	0·002795
32·3	0·3125	32·4	0·003125
33·8	0·3560	33·9	0·00356
35·7	Not measured	36	Not measured
(Conditions at peak load)			
Not measured	84·6	Not measured	0·613
(Conditions at fracture (in the neck))			

Tensile Test on Tube B2

Nominal stress p tons per sq. in	Percentage extension 10^2e	True stress $\sigma=p\ (1+e)$ tons per sq. in	True strain $\varepsilon=ln\ (1+e)$
1·62	0·012	1·62	0·00012
3·24	0·0245	3·24	0·008245
4·86	0·0375	4·86	0·000375
6·47	0·05	6·47	0·0005
8·10	0·063	8·10	0·00063
9·71	0·0755	9·71	0·000755
11·37	0·088	11·4	0·00088
12·96	0·1	13·0	0·001
14·6	0·113	14·6	0·00113
16·2	0·1255	16·2	0·001255
17·87	0·1375	17·9	0·001375
19·47	0·1505	19·5	0·001505
21·1	0·163	21·1	0·00163
22·74	0·1755	22·8	0·00175
24·32	0·1820	24·4	0·00182
25·9	0·2030	26·0	0·00203
29·2	0·236	29·3	0·00236
30	0·2595	30·1	0·00259
30·8	0·2880	30·9	0·00288
31·6	0·3250	31·7	0·00325
32·4	0·3800	32·5	0·00380
34·04	0·4115	34·1	0·00411
35·7	3	36 0	0·0296
(Conditions at peak load)			
Not measured	84·6	Not measured	0·613
(Conditions at fracture (in the neck))			

The position at which the stress-strain curves of the drawn material have been superimposed on the stress-strain curve of the undrawn material was determined from the total equivalent strain suffered by the tubes during drawing, found by measurement of the tube dimensions.

As regards the tensile tests on the tube material, the true stress and true strain were determined from the nominal stress and strain as follows : if e is the engineer's unit extension, r the unit reduction of area, ε the true strain, then

$$\varepsilon=ln(1+e)=ln\left(\frac{1}{1-r}\right) \quad . \quad . \quad . \quad (1)$$

Also, assuming that the volume of the test piece remains constant during the tensile test, if the true stress is σ and the nominal stress p then

$$\sigma=p(1+e) \quad . \quad . \quad . \quad . \quad (2)$$

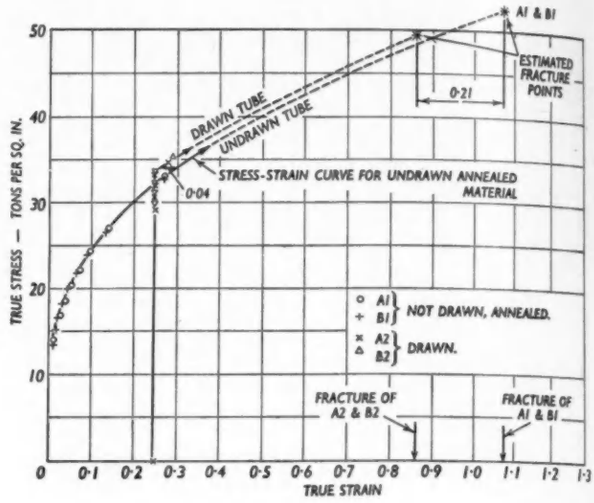


Fig. 2—True-stress true-strain curves

To determine the equivalent or effective strain suffered by the tubes during drawing, the following expression was used :

$$\bar{\varepsilon}=\sqrt{\frac{2}{3}(\varepsilon_1^2+\varepsilon_2^2+\varepsilon_3^2)} \quad . \quad . \quad . \quad (3)$$

This is a similar function of the strain tensor as the effective stress, given by the Maxwell (or von Mises) criterion, is of the stress tensor, although the use of total strains can strictly only be made provided that the strain ratios remain constant. This assumption is justifiable for the tube drawing process under discussion, in which the thickness of the tube can be shown to increase approximately in proportion to the reduction in radius at any stage, by reference to the analysis put forward by Swift.[1] In equation (3), ε_1, ε_2 and ε_3 are principal strains in the longitudinal, through thickness, and circumferential directions as shown by the inset element in Fig. 1(*a*). It should be noted that constancy of volume considerations require

$$\varepsilon_1+\varepsilon_2+\varepsilon_3=0 \quad . \quad . \quad . \quad (4)$$

(elastic strains being neglected).

For the tubes under consideration, the cross-sectional area, mean radius and tube thickness are related by the equation

$$\frac{A_0}{A_1}=\frac{r_{0m}t_0}{r_{1m}t_1} \quad . \quad . \quad . \quad (5)$$

(see Fig. 1(*a*) for notation of dimensions).

For the tube samples A1, B1, A2 and B2, measurements were made of these quantities and the following average results obtained :

$A_0=0{\cdot}38\text{in}^2$, $A_1=0{\cdot}31\text{in}^2$, $r_{0m}=0{\cdot}603\text{in}$, $r_{1m}=0{\cdot}479\text{in}$, $t_0=0{\cdot}099\text{in}$, $t_1=0{\cdot}103\text{in}$.

The value of t_1/t_0 is found, therefore, to be 1·04, and it is interesting to compare this figure with that derived from Swift's simplified theory. In this theory, friction and work-hardening effects were neglected, the Tresca criterion of yield was assumed, and it was assumed that the thickness of the material remained constant in formulating the equilibrium equation. As far as the thickness strains are concerned it can be seen from Swift's paper that there is little difference between this simplified model and a more exact analysis in which friction, work-hardening, thickness change, and the Maxwell (von Mises) yield criterion are all taken into account, at least for the value of r_{0m}/r_{1m} relating to the tubes under discussion. The equation derived by Swift is as follows :

$$ln\frac{t_1}{t_0}=2ln\frac{r_{0m}}{r_{1m}}+3ln(1-\tfrac{1}{2}ln\frac{r_{0m}}{r_{1m}}) \quad . \quad (6)$$

Substitution of the measured value of $r_{0m}/r_{1m}=1{\cdot}259$ into this equation gives the value of t_1/t_0 as 1·098.

The individual principal strain components required in equation (3) can now be determined, from the measured values, as follows :

$$\varepsilon_2=ln\frac{t_1}{t_0}=ln1{\cdot}04=0{\cdot}03921$$

$$\varepsilon_3=ln\frac{r_{1m}}{r_{0m}}=ln0{\cdot}794=-0{\cdot}23067$$

$$\varepsilon_1=-\varepsilon_2-\varepsilon_3=0{\cdot}19146.$$

Substituting these values in equation (3) gives the equivalent or effective strain as $\bar{\varepsilon}=0{\cdot}246$. (If the value of $t_1/t_0=1{\cdot}098$ given by Swift's theory is used, the equivalent strain is changed but little, its value then being given by $\bar{\varepsilon}=0{\cdot}232$.) A value of 0·246 has therefore been taken as the origin for the stress-strain curves of the drawn tubes A2 and B2 in Fig. 2.

Regarding the annealing tests, it was found that not all the tubes had exactly the same cross-sectional area and that there were actually two distinct groups, one having an average cross-sectional area of 0·242 square inch, the other 0·295 square inch (see Table V). The tubes of smaller area were

TABLE V—*U.T.S. of Samples* from Two Groups of Tubes ½in Diameter Used in the Annealing Tests*

Group	Sample No.	Cross section (square inch)	U.T.S. (tons per square inch)	Average (tons per square inch)
I	1	0·242	31·7	31·8
	2	0·242	31·9	
II	1	0·305	35·8	35·9
	2	0·304	35·6	
	3	0·290	36·4	

* Drawn tubes prior to annealing.

softer than the others and clearly came from a different cast of material. It was found best to express the results of these tests in the form of the ratio of the ultimate tensile strength after heat-treatment/U.T.S. before heat-treatment but after drawing as this ratio was substantially the same for both groups of tubes under similar conditions. This ratio was called z and is shown in Tables VI, VII and Fig. 3.

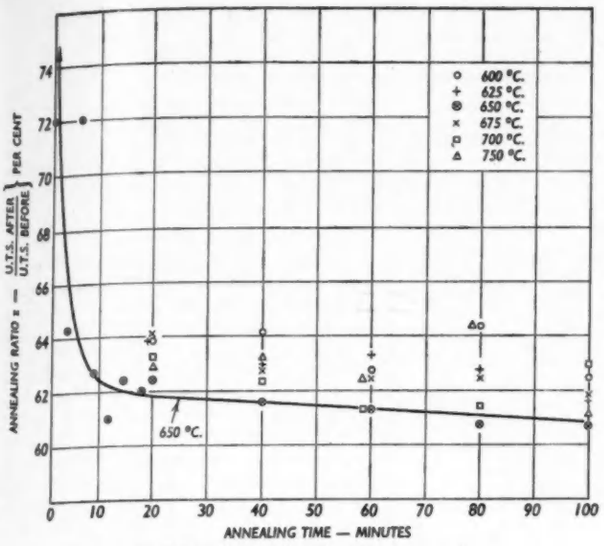
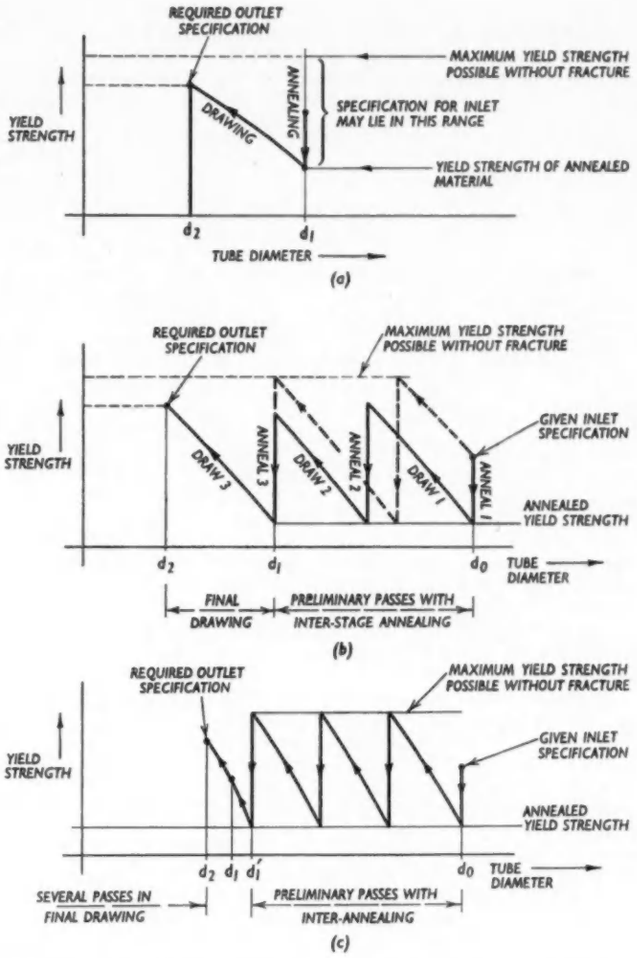


Fig. 3—Effect of annealing time and temperature



(a) Determination of d_0 when specification of drawn tube is given.

(b) Determination of preliminary passes required to reduce diameter from d_0 to d_2, before final drawing to d_2.

(c) Final drawing passes without inter-annealing.

(Right) Fig. 4—Diagrammatic representation of process specification

Discussion of Results

The production department of the plant in which these experiments were carried out was mainly concerned with three problems :

1. Prediction and control of the final mechanical properties of the tubes.

2. The variables of the annealing process, i.e. the effect of temperature in the furnace and annealing time and the accuracy with which they have to be controlled.

3. Considerations of process control variables (determining the amount of reduction per draw and number of draws and annealing operations in the process).

The following practical conclusions that can be drawn from this investigation provide some useful answers to these problems :

1. It can be seen from Fig. 2 that the amount of work-hardening imparted to the tubes by drawing is given approximately by computing the total effective strain suffered, using the formulae given in the previous analysis. Translation of the origin of the stress-strain curve of the drawn material to the right of the origin of the "master" curve by this amount of true strain then gives an indication of the resulting stress-strain curve of the drawn material, as well as an estimate of the ductility to be expected.

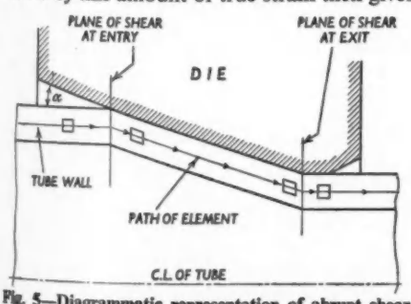


Fig. 5—Diagrammatic representation of abrupt shear at entry and exit

It might be thought that there would be additional work-hardening of the material due to shearing at entry and exit points, as shown diagrammatically in Fig. 5. If shearing occurred as shown the amount of shear strain would be $\gamma = \tan \alpha$, occurring at both entry and exit, giving a total additional effective strain of $2/\sqrt{3} \tan \alpha$. For these experiments α was 15 deg., so that the additional effective strain would have been 0·31, as estimated on this basis. Clearly, such a large amount of shearing did not take place at least for thin tubes of the type used, the deformation at entry and exit being predominantly bending in character.

It can be seen from Fig. 2 that the drawn tube exhibits less ductility than would be expected from these considerations, there being a discrepancy of 0·17 in the amount of true strain suffered by the tensile specimens of the drawn tube. It would also appear that the drawn material had, in fact, suffered an additional strain of 0·04 during the drawing process, since this amount of translation of the curve would be necessary to give better correspondence. Doubtless some additional shear strain was suffered during drawing, although no conclusions can be drawn from these few experiments. A more extended

Table VI—*Effect of Annealing Time on the U.T.S. of ¾in Tubes*

Temperature deg. Cent.	Time in furnace, minutes	20	40	60	80	100
600	Cross section (square inch)	0·291	0·298	0·301	0·284	0·291
	U.T.S. after annealing, tons per square inch	22·9	23·0	22·5	23·1	22·4
	Hardness after annealing (Rockwell)	55·0	52·5	58·0	60·0	62·0
	$z = 100 \frac{\text{U.T.S. after annealing*}}{\text{U.T.S. before annealing}}$	63·8	64·1	62·7	64·3	62·4
625	Cross section (square inch)	0·307	0·293	0·287	0·293	0·288
	U.T.S. after annealing	22·9	22·6	22·7	22·5	22·1
	Hardness	58·5	56·0	53·0	55·0	55·8
	z	63·8	62·9	63·2	62·7	61·6
650	Cross section (square inch)	0·293	0·246	0·242	0·248	0·242
	U.T.S. after annealing	22·4	19·6	19·5	19·3	19·3
	Hardness	56·0	31·0	29·0	32·0	32·0
	z	62·4	61·6	61·3	60·7	60·7
675	Cross section (square inch)	0·295	0·281	0·276	0·290	0·291
	U.T.S. after annealing	23·0	22·5	22·4	22·4	22·2
	Hardness	58·0	56·0	53·0	57·0	63·0
	z	64·1	62·7	62·4	62·4	61·8
700	Cross section (square inch)	0·290	0·262	0·246	0·245	0·284
	U.T.S. after annealing	22·7	19·8	19·5	19·5	22·6
	Hardness	47·0	32·0	30·5	31·0	54·0
	z	63·2	62·3	61·3	61·3	62·9
750	Cross section (square inch)	0·298	0·245	0·287	0·299	0·245
	U.T.S. after annealing	22·6	20·1	22·4	23·1	19·4
	Hardness	62·0	32·0	60·0	55·0	25·0
	z	62·9	63·1	62·4	64·3	61·1

* U.T.S. of the material prior to annealing is based on results given in Table V. z in this table is given in percentage

Technical Contributors Section *(continued)*

TABLE VII—*Effect of Annealing During the First Twenty Minutes*
(Furnace temperature 650 deg. Cent.)

Time (min.)	Cross section (square inch)	U.T.S. (tons per (sq. in)	Hardness (Rockwell)	Ratio * z percentage
0 ...	0·243	22·9	62	72·0
3 ...	0·288	23·1	69	64·3
6 ...	0·253	22·9	33	72·0
9 ...	0·305	22·5	55	62·7
12 ...	0·250	19·4	33	61·0
15 ...	0·290	22·4	56	62·4
18 ...	0·243	19·7	30	62·0

* $z = \frac{\text{U.T.S. after annealing}}{\text{U.T.S. before annealing}} 100$

U.T.S. before annealing for the drawn material is taken from Table V.

investigation would be necessary to give better correspondence, of the type undertaken by Blazynski and Cole,[3] for the tube ironing process, in which the complete stress-strain curve was determined by using the plane strain compression test. Also it should be remembered that no correction has been made for " necking " instability, and neglect of the consequent non-uniform distribution of stress in the cross section at fracture will lead to some error.

Thus, the true-stress true-strain curve can be used to predict the mechanical properties of the material for any given amount of reduction in area ; alternatively, to give final specified properties, the required amount of reduction can be specified.* It is worth while pointing out here that, as is well known, the ultimate tensile strength can also be predicted from the true-stress true-strain curve by locating the point at which the slope of the tangent to the curve has the same numerical value as the true stress.

2. The annealing experiments (Fig. 3) indicate that the softening process of the material in the first few minutes is fairly rapid and the ratio z levels off after about twelve minutes. This result immediately suggests that there is very little to be gained by prolonging the annealing time beyond this limit, so that the productive capacity of the furnace is, in fact, much higher than the present figure, which was based on a cycle time of thirty minutes. Furthermore, Fig. 3 suggests that the annealing process is not sensitive to variation of furnace temperature within the range examined in the experiments. Had the temperature played an important role, one would have expected the annealing curves to occur in the order of rising temperature with that of 750 deg. Cent. being the lowest. The scatter of results in Fig. 3 implies, however, that as the temperature is not significant, (*a*) annealing may be carried out at a comparatively low temperature, say 600 deg. to 650 deg. Cent., which is more economical to operate at, and (*b*) there is no need to regulate the furnace temperature within close limits.

3. The main parameters through which the process can be controlled are those of the amount of reduction and the number of reductions per tube (there seems to be little point in using partial annealing as the reduction in yield strength is too rapid during the effective annealing cycle to lend itself to control by annealing time). Two situations may arise :

(*a*) The physical dimensions and mechanical properties of the final tube are determined by the customer's requirements : For given mechanical properties of raw material, the amount of reduction in area is calculated from the true-stress true-strain curve (or Fig. 4(*a*)), so that the physical dimensions of the tube prior to drawing can be specified. The maximum improvement in strength is provided by the maximum reduction which is possible, without causing fracture during the drawing process, although the consequent reduction in ductility must be borne in mind. This latter can be estimated from the stress-strain curve. If the price of the raw material per unit weight is practically independent of tube diameter, it is then best to have only one pass in the drawing process, reducing the diameter from d_1 to d_2 (Fig. 4(*a*)), as any additional passes with inter-stage annealing will only increase the cost of the process without improving the mechanical properties of the material.

(*b*) The specification of both the final tube and the raw material may be fixed, so that the diameter d_0 of the inlet (prior to drawing) is determined by the supplier and is not subject to selection by the plant. Provided $d_0 > d_1$, where d_1 is the diameter required prior to the last drawing (determined as in case (*a*) above), the procedure would simply be to reduce the diameter of the tube from d_0 to d_1 in the smallest possible number of passes with inter-stage annealing (Fig. 4(*b*)). Alternatively, one could start with a number of passes with inter-stage annealing, reducing the diameter from d_0 to d'_1, (Fig. 4(*c*)), followed by passes without inter-stage annealing, through which the strength of the material is successively improved until the desired value is attained at the required diameter d_2 (provided the final material has sufficient remaining ductility). This last procedure might be adopted if it were necessary to produce tubes of high dimensional accuracy and very good surface finish. Depending on the relative values of d_0 and d_1, the shape of the stress strain curve, and the hardness of the supplied tubes, it might be possible to dispense with the first annealing and proceed as shown by the broken line in Fig. 4(*b*). Such a course of action would depend largely on having the supplied tubes of consistent hardness, to avoid fracture during the first drawing.

Conclusions

It is clear from this investigation that a good estimate of the actual drawing reduction required to confer any given properties on the tube material can be obtained by judicious use of the complete true-stress true-strain curve for the annealed material, within the limitations imposed by the ductility of the material. In this way not only the strength of the drawn tube but also its ductility can be controlled and predicted. For any given required mechanical properties of the final tube, the properties and diameter of the tube to be drawn can, therefore, be specified.

The annealing process is rapid to begin with, but then it becomes increasingly slower, so that an effective annealing time may be determined, beyond which there is little to be gained by leaving the tubes in the furnace. Accurate temperature control seems to be superfluous, as the annealing was not found to be sensitive to furnace temperature within the investigated range.

Acknowledgments

Acknowledgment is due to two former students of one of the authors, Messrs. R. Olami and A. Ziv, and the Building Research Station of the Israel Institute of Technology for carrying out some of the strength and hardness tests of specimens. The authors would also like to thank the Near East Tube Company, Ltd., Haifa, for providing facilities for the study of the process at their plant, and Miss Janet Piggott, of Imperial College, for measuring the tubes.

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* These conclusions relate specifically to the conical die used in these experiments, but would doubtless apply also to dies of circular profile, by use of the appropriate analysis, described by Johnson.[2]

Structural Behaviour of a Spherical Pressure Vessel

By D. S. HOUGHTON, M.Sc. (Eng.), A.M.I.Mech.E., A.F.R.Ae.S., and G. A. ACKROYD, Ph.D.

The strain distribution at the junction of a spherical reactor vessel and its supporting skirt is investigated using electrical resistance strain gauges with " Perspex " models. The experimental results are verified theoretically for the following structural configurations . (a) *Spherical reactor vessel having outer cylindrical skirt only ; and* (b) *Spherical reactor vessel having both inner and outer cylindrical skirts. Throughout the investigation it is assumed that no axial loading exists in the skirt structure and that the loading is appropriate to a reactor vessel under uniform radial pressure.*

THE economic design of nuclear reactor shell structures has been a subject for discussion amongst structural engineers during the past few years. Many ingenious schemes have been investigated and one of the designs which seems to be acceptable both structurally and economically, consists of a spherical reactor containment vessel, supported by a cylindrical skirt. In addition, an internal skirt is used to support the reactor element, and the two skirts are conveniently formed to the same diameter in order to facilitate load transfer to the ground. The skirts are welded to the sphere which results in a rigid joint between the two structural elements. One design requirement is that the spherical vessel shall contain the reactive material in the event of an accident, in which case considerable pressure forces may be developed.

An interesting problem which has arisen as a result of this design is the investigation of the stresses which are induced in the sphere due to restraining action of the cylindrical skirts. In addit on, stresses will be induced in the skirts, since by their action of restraining the deformations of the sphere, shear forces and bending moments are induced.

The function of these shear forces and bending moments is to deform the structure

locally so that at the joint the structure will remain continuous. These induced forces and moments create the stresses which are referred to throughout this article as discontinuity stresses, which are local but can be high in the region of the discontinuity. These stresses are in addition to the simple membrane solution and providing that the structure behaves in a linear manner, the Principle of Superposition can be used to find the resultant stress system.

An exact knowledge of the magnitude of the induced discontinuity stresses is clearly desirable, owing to the serious consequences of any rupture of the containment vessel.

This articles gives an experimental and theoretical verification of the stresses induced in a structure consisting of a spherical shell and constraining external and internal cylindrical skirts. The loading is for the case of the sphere under uniform radial pressure and the cylindrical skirts are not loaded in an axial direction.

This work was conducted in the Design Department of the College of Aeronautics, Cranfield.

Theoretical Verification

For the spherical nuclear reactor vessel, the ratio of the shell radius to wall thickness is of the order of 120 to 1, so that clearly the well-known thin shell theories are acceptable as a basis for the analysis. For such shells the radial stresses through the thickness may be neglected, and the shear stresses may be considered simply to be distributed parabolically across the section.

The general equilibrium equations for both the case of axi-symmetric shells and shells having the form of a surface of revolution, and symmetrically loaded were established by Love (1906). The results are developed by Timoshenko and Woinowsky-Kreiger[1], who show some approximate methods of analysing the stresses and deflections in shells having a spherical form.

The method which can be used to establish the stresses and deflections in a spherical shell was developed by Reissner (1912) and Meissner (1913). Further simplifications were made by Geckeler (1926) and Meissner (1929), who made the assumption that in the narrow band where the induced bending and shear forces are experienced, considerable simplification can be obtained by replacing this band of the sphere by the tangent conical band. To this equivalent band the equations developed for a circular cylinder are used.

Later an improved solution was obtained by Hetenyi (1938) who found by suitably modifying the form of the solution, a more accurate approximation could be obtained.

Recently two papers have been produced which apply these approximate solutions to the case of a structure consisting of a pressurised spherical shell having inner and outer skirts, which in addition could be subject to a variable temperature loading.

The first approximate method of Geckeler-Meissner was used by Houghton and Chan[2] and the second Hetenyi method was used to solve the same problem by Hicks[3]. In both cases the induced shear forces and bending moments were established from which the magnitude of the discontinuity stresses can be quickly found.

In the following investigation, the work will be based on the paper by Houghton and Chan, since the form of the resulting equations is very much simplified. Investigations which have been carried out by the authors suggest that the errors involved by using the Meissner-Geckeler approximation are within the accuracy obtained in the manufacture of the models used in this investigation.

For the purpose of showing the effects of including the internal skirt, it is interesting to study the problem in two parts.

(*a*) When the external skirt only is included.

(*b*) When both internal and external skirts are used.

Discontinuity Conditions at Intersection with External Skirt

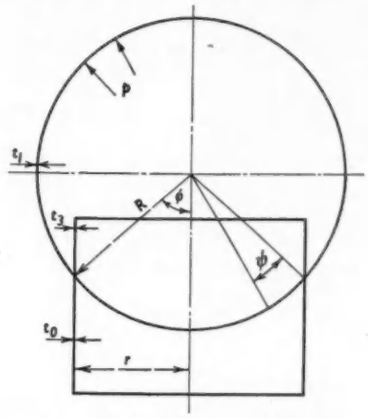


Fig. 1—The geometry of the pressurised sphere and intersecting cylinders

If a hollow sphere, shown in Fig. 1, of radius R and wall thickness t_1 is subjected to a pressure differential p the radius is increased by an amount

$$\Delta R=\frac{pR^2}{2Et_1}(1-\rho)$$

where

ρ = Poisson's ratio

and

E = Young's modulus.

If this displacement is resolved in the plane which cuts the sphere at an angle ϕ subtended from its centre, i.e. in the radial direction of the intersecting cylinder then

$$\Delta R\sin\phi=\frac{prR}{2Et_1}(1-\rho)=d \quad . \quad (1)$$

The presence of the intersecting cylinder tends to prevent this free expansion and as a consequence moments and forces are induced in the sphere and cylindrical structure.

If the sphere and cylinder are considered to be cut along the junction of the structure, Fig. 2, a self-equilibrating system of forces

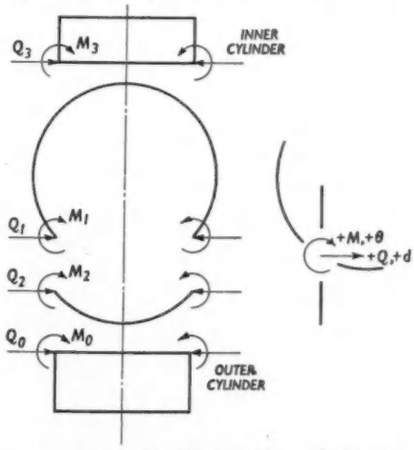


Fig. 2—The self-equilibrating system and sign convention

and moments is shown to exist in each part of the structure. Their effect is purely local and their function is to deform the structure so that under load it remains continuous. The magnitudes of these induced forces and moments are found from conditions of compatibility.

The relation between the deformation and forces in the cylinder will now be examined. By adopting the sign convention shown in Fig. 2, the deflection d and rotation θ, due to the application of a moment/in(M) and shear force/in(Q), can be found for the various parts of the structure.

For the outer cylinder subjected to an edge moment M_0 and edge force Q_0 the deflections are given by Timoshenko and Woinowsky-Kreiger (Art. 114) as

$$d_0=\frac{1}{2k^3D}[\beta M_0\psi(kx)+Q_0\theta(kx)] \quad . \quad (2)$$

and

$$\theta_0=\frac{1}{2k^2D}[2\beta M_0\theta(kx)+Q_0\phi(kx)] \quad . \quad (3)$$

where

$$k^4=\frac{3(1-\rho^2)}{r^2t_0^2} \quad \text{and} \quad D=\frac{Et_0^3}{12(1-\rho^2)} \quad . \quad . \quad . \quad . \quad . \quad (4)$$

The die away is characterised by kx and it is only when the cylinder length is small that it becomes a significant parameter.

The deflection and rotation at the edge where the moments and forces are applied become simply

$$d_0=\frac{1}{2k^3D}[kM_0+Q_0] \quad . \quad . \quad (5)$$

and

$$\theta_0=\frac{1}{2k^2D}[2kM_0+Q_0] \quad . \quad . \quad (6)$$

The deflections and rotations of the two parts of the spherical shell, when these parts are subjected to edge forces and moments are to be found in Timoshenko and Woinowsky-Kreiger (Art. 130).

For the spherical shell outside the circumference of the cylinder (subscript 1), the edge deflections and rotations can be expressed as

$$d_1=\frac{2\lambda R}{Et_1}\sin^2(\pi-\phi)Q_1-\frac{2\lambda^2}{Et_1}\sin(\pi-\phi)M_1 \quad (7)$$

and

$$\theta_1=-\frac{2\lambda^2}{Et_1}\sin(\pi-\phi)Q_1+\frac{4\lambda^3}{ERt_1}M_1 \quad . \quad . \quad . \quad (8)$$

where

$$\lambda_4=3(1-\rho^2)(R/t_1)^2.$$

In a similar manner, the edge deflections and rotations for that part of the spherical shell inside the cylinder (subscript 2) become

$$d_2=2\lambda R\frac{\sin^2\phi}{Et_1}Q_2+2\lambda^2\frac{\sin\phi}{Et_1}M_2 \quad . \quad (9)$$

and

$$\theta_2=\frac{2\lambda^2}{Et_1}\sin\phi Q_2+\frac{4\lambda^3}{ERt_1}M_2 \quad . \quad . \quad (10)$$

Once the magnitudes of the self equilibrating system of edge forces Q_0, Q_1, Q_2 and moments M_0, M_1, M_2 have been established it is a simple matter to investigate their die-away distributions.

If the joint between the sphere and cylinder is assumed rigid, i.e. it does not distort when the structure is deflected then

$$\theta_0=\theta_1=\theta_2 \quad . \quad . \quad . \quad . \quad (11)$$

Equation (11) yields

$$\frac{4\lambda^3}{ERt_1}M_1-2\lambda^2\frac{\sin\phi}{Et_{11}}Q_1-\frac{1}{2k^2D}(2kM_0+Q_0)=0 \quad . \quad . \quad . \quad (12)$$

and

$$\frac{2\lambda^2}{Et_1}\sin\phi(Q_1+Q_2)+\frac{4\lambda^3}{ERt_1}(M_2-M_1)=0 \quad . \quad . \quad . \quad (13)$$

For structural continuity the deflections in

Technical Contributors Section (*continued*)

each part of the sphere must be identical i.e. $d_1=d_2$ to give

$$\frac{2\lambda R\sin^2\phi}{Et}(Q_2-Q_1)+\frac{2\lambda^2\sin\phi}{Et}(M_1+M_2)=0 \quad . \; . \; . \quad (14)$$

In addition the deflection of the sphere and cylinder must be compatible. The total inward deviation of the sphere is d_1-d where d is given by equation (1), hence the compatibility equation gives

$$d_0=d_1-d,$$

or

$$\frac{1}{2k^2D}[kM_0+Q_0] =\frac{2\lambda R}{Et}\sin^2\phi Q_1-\frac{2\lambda^2}{Et}\sin\phi M_1-\frac{prR}{2Et}(1-\rho) \quad . \; . \; . \; . \; . \quad (15)$$

Finally the two equilibrium equations at the joint yield

$$Q_0+Q_1+Q_2=0 \quad . \; . \; . \quad (16)$$

and

$$M_0+M_1+M_2=0 \quad . \; . \; . \quad (17)$$

The six equations (12) to (17) enable the induced forces and moments to be evaluated.

The solution of these equations can be conveniently expressed as

$$\left.\begin{aligned} M_0&=\frac{\xi_0}{\Delta},\ M_1=\frac{\xi_1}{\Delta},\ M_2=\frac{\xi_2}{\Delta}\\ Q_0&=\frac{\xi_0}{\Delta},\ Q_1=\frac{\xi_1}{\Delta},\ Q_2=\frac{\xi_2}{\Delta}, \end{aligned}\right\} \quad . \; . \quad (18)$$

where

$$\left.\begin{aligned} \Delta&=a^4\left(1+\frac{4d}{b}\right)+4k^2a^2bd\left(1+\frac{2d}{b}\right)\\ \xi_0&=8k\,a^2de \end{aligned}\right\} \quad (19)$$

and

$$\zeta_0=-2c(a^2+4k^2bd)e$$

The remaining unknowns can be expressed in terms of ξ_0 and ζ_0 to give

$$\left.\begin{aligned} \xi_1&=-\frac{\xi_0}{2}-\frac{a}{2c}\zeta_0\\ \xi_2&=-\frac{\xi_0}{2}+\frac{a}{2c}\zeta_0\\ \zeta_1&=-\frac{\zeta_0}{2}-\frac{c}{4a}\xi_0\\ \zeta_2&=-\frac{\zeta_0}{2}+\frac{c}{4a}\xi_0 \end{aligned}\right\} \quad . \; . \quad (20)$$

and

The geometrical constants are

$$\left.\begin{aligned} a&=\frac{2\lambda^2r}{R}\\ b&=\frac{2\lambda r^2}{R}\\ c&=\frac{4\lambda^3}{R}\\ d&=2kr^2\frac{t}{t_0} \end{aligned}\right\} \quad . \; . \quad (21)$$

and

$$e=\frac{prR}{2}(1-\mu)$$

Spherical Shell Intersected by Inner and Outer Cylindrical Skirts

For this design the procedure adopted previously can be extended to include the inner cylinder.

If the thickness of the inner cylinder is t_3, then the inclusion of this additional structure will introduce two more unknowns Q_3 and M_3 which represent the shear force per inch and bending moment per inch at the edge of the inner cylinder.

Two more equations are available to evaluate these quantities, which are determined from the conditions of continuity of the two cylinders

The deflection of the edge of the inner skirt is

$$d_3=\frac{1}{2k_3^2D_3}(-k_3M_3+Q_3) \quad . \; . \quad (22)$$

and the rotation is

$$\theta_3=\frac{1}{2k_3^2D_3}(2k_3M_3-Q_3) \quad . \; . \quad (23)$$

where

$$\left.\begin{aligned} k_3^4&=\frac{3(1-\rho^2)}{r^2t_3^2},\\ \text{and}\quad D_3&=\frac{Et_3^3}{12(1-\rho^2)}. \end{aligned}\right\} \quad . \; . \; . \; . \quad (24)$$

The equations of continuity of the cylinder yield

$$d_0=d_3 \text{ and } \theta_0=\theta_3 \quad . \; . \; . \quad (25)$$

From equations (5) and (22), using the first condition in equation (25),

$$M_0+\lambda_1M_3+\frac{1}{k}\left(Q_0-\lambda_1\frac{k}{k_3}Q_3\right)=0 \quad (26)$$

where

$$\lambda_1=\left(\frac{k}{k_3}\right)^2\frac{D}{D_3}.$$

If $t_0=t_3$, then equation (25) reduces to

$$M_0+M_3+\frac{1}{k}(Q_0-Q_3)=0 \quad . \; (26a)$$

From equations (6) and (23), using the second condition in equation (25)

$$M_0-\lambda_1\frac{k_3}{k}M_3+\frac{1}{2k}(Q_0+\lambda_1Q_3) \quad . \; (27)$$

If $t_3=t_0$, then equation (29) reduces to

$$M_0-M_3+\frac{1}{2k}(Q_0+Q_3)=0 \quad . \; (27a)$$

With the addition of M_3 and Q_3 at the joint, the equations of equilibrium become

$$Q_0+Q_1+Q_2+Q_3=0 \quad . \; . \quad (28)$$

and

$$M_0+M_1+M_2+M_3=0 \quad . \; . \quad (29)$$

The equations (12) to (15) are still applicable for the case of this structure, so that together with (26), (27), (28) and (29), these are sufficient equations to evaluate the eight unknown forces and moments. If the inner and outer cylinders have the same thickness, then the solution is

$$\left.\begin{aligned} -Q_0&=Q_1=Q_2=-Q_3=ce/\zeta\\ M_1&=-M_2=ae/\zeta\\ M_0&=-M_3=ce/2k\zeta \end{aligned}\right\} \quad . \; . \quad (30)$$

where

$$\zeta=a^2+dc/2$$

The values of the coefficients used in equation (30) are to be found in equation (21).

Examination of Stresses in the Structure

So far, the edge forces and moments arising in each part of the structure at the joint have been established for two configurations. In order to compute the distribution of shear and bending stresses in the region of the discontinuity for each configuration, the manner with which the edge forces and moments die away must first be examined.

(*a*) For the outer cylinder, the distribution of bending moment per inch, M_x, and shear force per inch, Q_x, at a distance x from the joint, shown in Fig. 3, can be found by using the derivation of equation (3).

Hence

$$M_x=e^{-kx}\left[M_0(\cos kx+\sin kx)+\frac{Q_0}{k}\sin kx\right]$$

and

$$Q_x=e^{-kx}[Q_0(\cos kx-\sin kx)-2kM_0\sin kx] \quad . \; . \; . \quad (31)$$

and in the hoop direction,

$$M_\theta=\rho M_x,$$

and

$$T_\theta=-2kre^{-kx}[kM_0(\cos kx-\sin kx)+Q_0\cos kx],$$

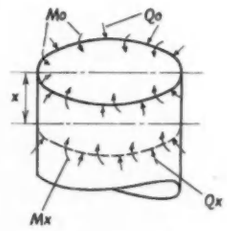
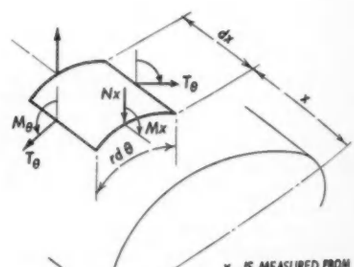


Fig. 3—The forces and moments in the cylindrical skirt



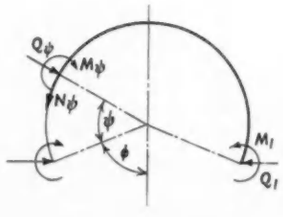
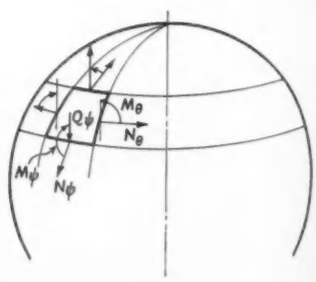


Fig. 4—The forces and moments in the sphere



(*b*) For the inner cylinder

$$\left.\begin{aligned} M_x &= -e^{-k_3 x}\left[M_3(\cos k_3 x + \sin k_3 x) - \frac{Q_3}{k_3}\sin k_3 x\right] \\ Q_x &= e^{-k_3 x}[Q_3(\cos k_3 x - \sin k_3 x) + 2k_3 M_3 \sin k_3 x] \\ M_\theta &= \rho M_x \\ &\text{and} \\ T_\theta &= 2k_3 r e^{-k_3 x}[k_3 M_3(\cos k_3 x - \sin k_3 x) - Q_3 \cos k_3 x] \end{aligned}\right\} \quad (32)$$

(*c*) For the sphere outside the cylinder.

Due to the application of an edge force N_1 and edge moment M_1 (Fig. 4), the forces and moments at an angle ψ from the joint become,

$$\left.\begin{aligned} M_\psi &= e^{-\lambda\psi}\left[\sqrt{2}\,M_1 \sin(\lambda\psi + \pi/4) - \frac{RQ_1}{\lambda}\sin\phi \sin\lambda\psi\right] \\ M_\theta &= \rho M_\psi \\ Q_\psi &= e^{-\lambda\psi}\left[\frac{2\lambda M_1}{R}\sin\lambda\psi - \sqrt{2}\,Q_1 \sin\phi \sin(\lambda\psi - \pi/4)\right] \\ N_\psi &= -Q_\psi \cot(\phi - \psi) \\ &\text{and} \\ N_\theta &= -2\lambda\, e^{-\lambda\psi}\left[Q_1 \sin\phi \cos\lambda\psi + \sqrt{2}\frac{\lambda M_1}{R}\sin(\lambda\psi - \pi/4)\right] \end{aligned}\right\} \quad (33)$$

(*d*) For the sphere inside the cylinder.

Due to the application of an edge force N_2 and edge moment M_2, the forces and moments at an angle ψ from the joint become

$$\left.\begin{aligned} M_\psi &= -e^{-\lambda\psi}\left[\sqrt{2}\,M_2 \sin(\lambda\psi + \pi/4) + \frac{RQ_2}{\lambda}\sin\phi \sin\lambda\psi\right] \\ M_\theta &= \rho M_\psi, \\ Q_\psi &= -e^{-\lambda\psi}\left[\frac{2\lambda M_2}{R}\sin\lambda\psi + \sqrt{2}\,Q_2 \sin\phi \sin(\lambda\psi - \pi/4)\right] \\ N_\psi &= -Q_\psi \cot(\phi - \psi) \\ &\text{and} \\ N_\phi &= -2\lambda e^{-\lambda\psi}\left[Q_2 \sin\phi \cos\lambda\psi + \sqrt{2}\frac{\lambda M_2}{R}\sin(\lambda\psi - \pi/4\right] \end{aligned}\right\} \quad (34)$$

The distribution of bending and shear stresses in each cylindrical skirt can now be established from equations (31) and (32), and in both parts of the sphere from equations (33) and (34). The values of the edge forces and moments are given by equation (30) in terms of the loading and the various structural parameters.

Having found the distribution of shear force and bending moment in the structure it is now a simple matter to evaluate the stress distribution. For the sphere, since it is pressurised, a membrane stress should be superimposed on the discontinuity stress system where appropriate to give the final stress distribution.

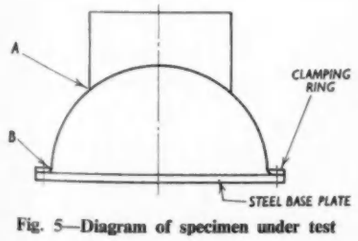


Fig. 5—Diagram of specimen under test

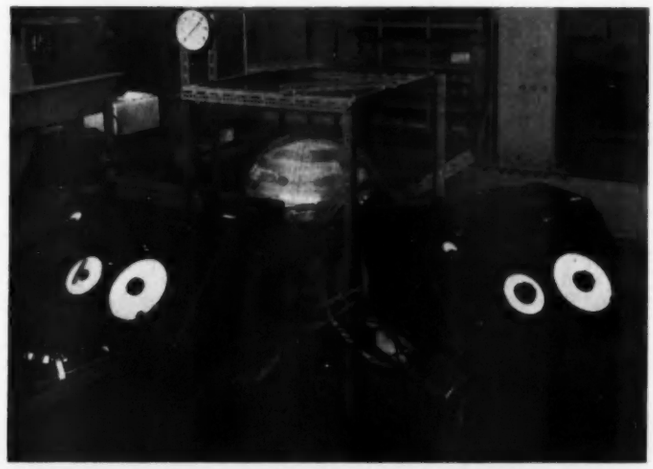


Fig. 6 — Details of the "Perspex" hemisphere used for initial calibration purposes

Description of Experimental Models and Test Rig

In view of the difficulty in manufacturing a complete sphere, it was decided that a model of the type shown in Fig. 5 would give a satisfactory representation of the reactor structure. The rigid baseplate caused considerable bending in the region *B* but this is localised and does not affect the stress distribution around the skirt joint at *A*.

Two types of models were constructed, one of aluminium and the other " Perspex." The aluminium hemisphere was spun from a sheet of 16 S.W.G. L.59 material, and the cylinder was rolled and seam welded using 16 S.W.G. L.16 material.

For the aluminium specimen, the manufacture of the joint between the cylinder and hemisphere proved to be the most serious disadvantage. Several forms of joint were tried but none of them was really satisfactory. The initial tests were carried out using a spun jointing ring which was bolted to each part of the structure, but this design was abandoned since the jointing ring tended to mask the discontinuity effects at the joint. A narrow machined jointing ring which was bonded to both parts of the structure was tried, but the " Araldite " bond proved to be too flexible and the peak strains were not realised. For this reason welding and brazing techniques were tried, with and without jointing rings, but it was found that the specimens suffered serious permanent distortion immediately adjacent to the weld area. The experiments using aluminium models were discontinued and the remaining work was carried out on " Perspex " models.

The initial tests showed that small neat joints of great strength and rigidity could be

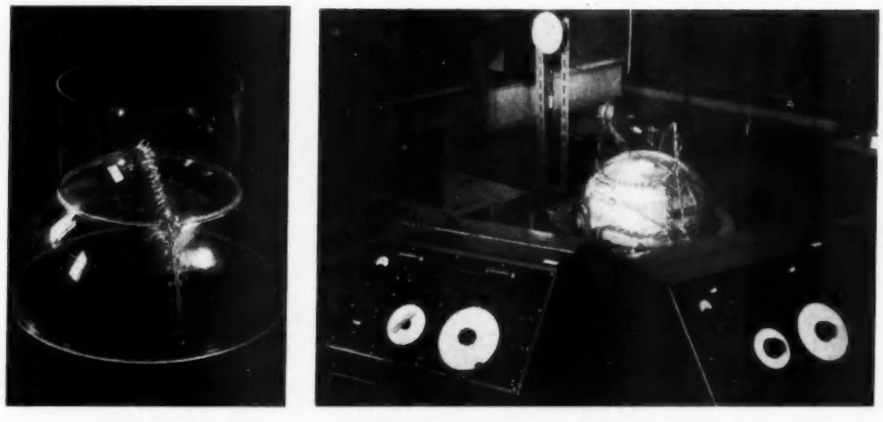
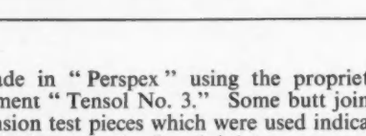


Fig. 7—The test rig and strain gauge positioning

Technical Contributors Section (*continued*)

made in " Perspex " using the proprietary cement " Tensol No. 3." Some butt jointed tension test pieces which were used indicated that the strength of such joints was approximately 90 per cent and that the rigidity was of the same order as the original material. " Perspex " may be conveniently shaped at its softening temperature of 160 deg. Cent., and is thus an excellent material for model



(*a*) Hemisphere only
(*b*) Hemisphere with outer cylinder
(*c*) Hemisphere with inner and outer cylinder

Fig. 8—Test models

manufacture. It does however suffer from the following disadvantages when used in conjunction with the electrical resistance type of strain gauge.

(*a*) " Perspex " has a low Young's modulus and the stiffening effect of the gauge may be considerable. From the values given by Richards,[4] the effective stiffness of the shell structure at the joint is increased by a factor of approximately 1·09.

(*b*) The cross sensitivity of the strain gauges is increased because " Perspex " has a high Poisson's ratio. This is particularly apparent for the smaller gauges such as the Tinsley type 6H which were used.

It was considered that these effects, whilst clearly undesirable, were not prohibitive.

" Perspex " hemispheres were supplied by I.C.I. Plastics Division to a 30in nominal diameter. The thickness varied continuously from 0·080in at the crown to 0·180in at the flange. The cylinders were manufactured from $\frac{1}{8}$in " Perspex " sheet to 20in diameter using a hot forming process. It was considered that these models were sufficiently large for the efficient use to be made of the electrical resistance type of strain gauge.

Fig. 6 shows one of these models mounted in the test rig. In this instance the skirt is not in position since this particular model was used solely for calibration purposes. Fig. 7 shows the same hemisphere with the full skirt and all the gauges in position. Tinsley type 6H gauges were used in conjunction with Savage and Parsons recording equipment. Type 6H gauges are not quite as accurate as the larger type 6K, but they were used only in the immediate neighbourhood of the joint because of their smaller gauge length. Altogether 120 active gauges were mounted over a full diametral section as it was found that this large number of gauges was necessary in order to make a complete investigation of the problem.

" Perspex " is subject to brittle fracture, and in order to reduce the effects of a possible explosion, a wooden filler block was used, together with a tarpaulin, supported by the framework shown in Fig. 6. This enclosure also helped to maintain constant temperature conditions. Thermocouples were mounted on the gauge line both inside and outside the hemisphere in order to provide a check on temperature fluctuations throughout the test period. Temperature changes are even more important with " Perspex " than with other model materials, since its elastic properties are affected.

A soft rubber seal clamped between the hemisphere flange and the baseplate with a clamping ring was found to be sufficient to prevent air leakage during test.

Test Procedure

The hemisphere was pressurised to a maximum of 10 lb per square inch and the gauges balanced at this pressure. When temperature conditions had become stabilised, gauge readings were taken at suitable pressure decrements down to zero. It was necessary to restrict the gauge current to 10mA in order to prevent an excessive temperature rise at the gauge line. A rise of less than 1 deg. Cent. was measured by the thermocouples under these conditions. It was

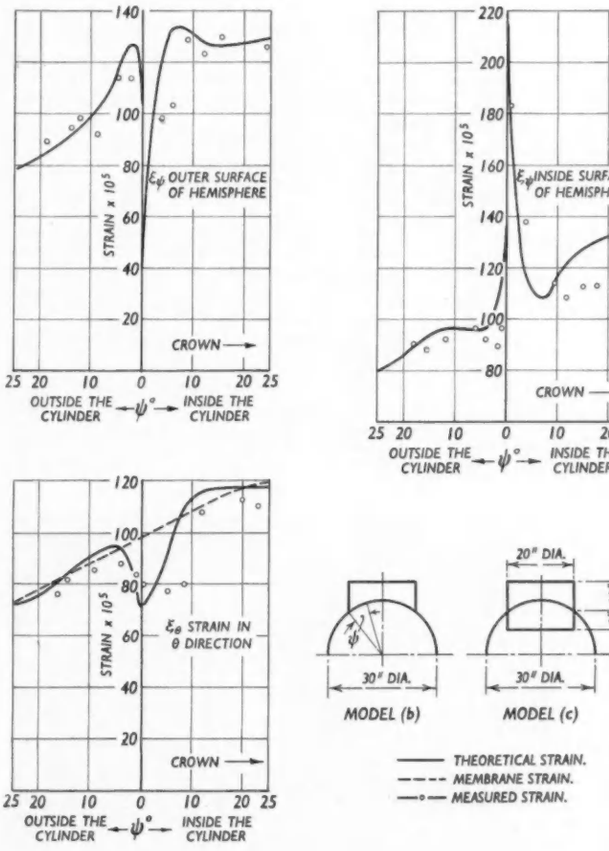


Fig. 9—Strain distribution across skirt joint for model (*b*)

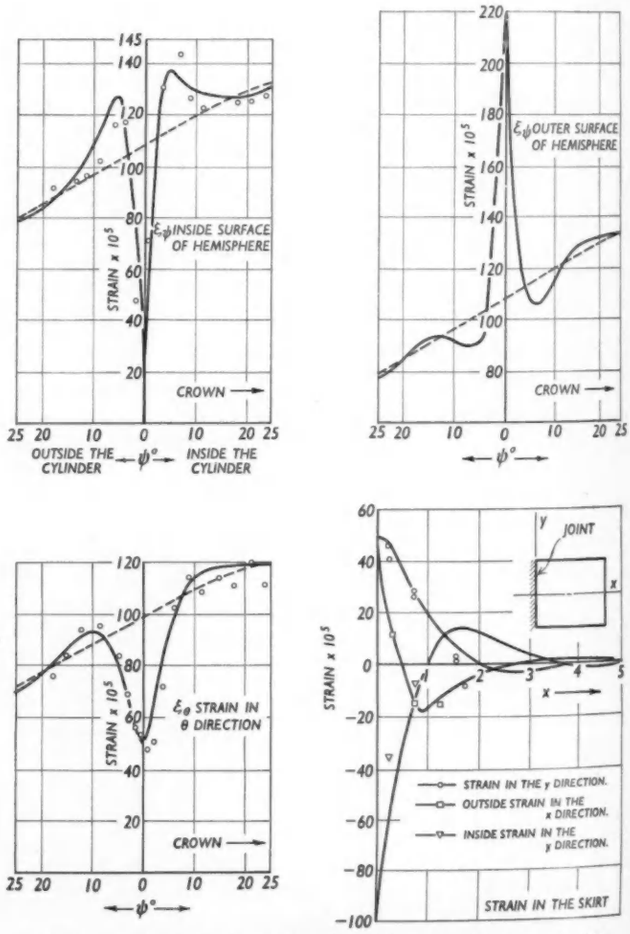


Fig. 10—Strain distribution in the region of the skirt joint for model (*c*)

found that repeatable results could be obtained using this rather small gauge current provided that extra care was taken to compensate for the reduced sensitivity.

The models (*a*), (*b*), and (*c*) in Fig. 8) were tested in that order, using the same hemisphere for each experiment. Model (*a*) was used for proving the test rig and assessing the reliability of the gauges. It was also used to investigate the edge effect due to the clamping restraint, and to estimate the value of Young's modulus for the material. It was found from these preliminary tests that the gauge readings varied linearly with pressure and were repeatable for any given temperature. The membrane force was constant except for the region within 20 deg. from the flange, where considerable bending took place. Values of $E\theta$ and $E\psi$, whilst constant around the gauge line, differed by as much as 8 per cent. It is known that "Perspex" is subject to directional variations of this nature and it seemed probable that this difference existed in the sheet from which this hemisphere had been originally made.

Models *b* and *c* were constructed from the model *a* such that the same gauges and hemisphere were used for each experiment. The results for *b* and *c* are shown in Figs. 9 and 10.

Discussion of Results

Strain rather than stress in the region of the joint has been used as a basis for comparison between the theoretical and experimental results, since it appears to the authors that this is a more direct approach. It is, in fact, found to be a rather more accurate process when using electrical resistance strain gauges since they are subject to the "cross-sensitivity effect."

The experimental results show a generally good agreement with the analytical ones. It should be noted, however, that the membrane strain is not constant, but increases towards the crown since the hemisphere was of variable thickness.

The discontinuity forces at the joint were calculated using an assumed value of Poisson's ratio of 0·35, as quoted by I.C.I. Plastics Division. It was decided that the difficulties of measuring Poisson's ratio in the region of the joint would have been prohibitive. The analysis also assumes a uniform shell thickness. This is an adequate assumption since the discontinuity forces are dependent upon the local stiffness of the shell at the joint and not of the shell as a whole. The thickness variation has been taken into account when calculating the die away functions however.

That the skirt does not introduce appreciable discontinuity effects may be judged from the strain curves. For this particular model, the maximum strain at the joint was approximately twice that due to membrane action.

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Retracing the Steps in the Design of a Special Slide Rule

By A. W. SWAN, B.A. Sc., A.M.I.Mech.E.

WHEN one has acquired any branch of knowledge it is usually difficult to retrace one's probably painful steps taken in acquiring that knowledge, and it is quite a temptation to adopt the "of course" attitude and to look down, probably unconsciously, on those who do not have the knowledge in question. The Earl of Halsbury recently suggested in a talk to the Operational Research Society that when a mathematician feels puzzled at the lack of mathematical knowledge in those around him he should examine himself on his own knowledge of, say, endocrinology.

The following notes attempt to recapture the processes of thought behind the design of a special slide-rule which was to be used by clerks not trained in mathematics in working out mill tonnage rates in a large steel works. It is hoped that they will be found useful in solving the problems which come up in the design of any special slide-rule, more particularly as while there have been a number of publications on the design and use of nomographs, from the days of d'Ocagne onwards, very little has been written on the parallel subject of special slide-rules.

The calculation which it was hoped to simplify and reduce in operator's time is not particularly difficult, being a triple multiplication. It has, however, several features which are rather awkward from the "long-hand" and even desk calculating machine aspects. It is carried out many times a day, and some kind of simplifying device was certainly justified. The purpose of the calculation is to give the tons of rails rolled per hour, (*a*) "raw," i.e. weight of ingots rolled multiplied by the number rolled; (*b*) corrected by product factor; light rails are rolled more slowly than heavy rails, and a compensating factor is used to standardise rolling rates; (*c*) corrected for mill stoppages on the basis that the mill would have continued running at a constant rate for the whole hour if the stoppages had not occurred.

Answers for (*a*), (*b*), and (*c*) are required separately, but it was desired, if possible, to make the whole calculation one continuous operation.

Further complications were that there were four types of unit; weight of ingot in hundredweights, product factor as 1·0, 1·1, 1·2, &c., weight rolled in tons, and stoppages in minutes.

The actual calculation can be expressed algebraically as follows:

If

a = Weight of ingot in hundredweights.
n = Number of ingots rolled in an hour.
b = Product factor.
c = Stoppages in the hour in minutes.
T = "Raw" tons rolled per hour.
T_b = "Raw" tons corrected for product.
T_c = "Raw" tons corrected for product and stoppages.

Then

$$T=\frac{a}{20}\times n$$

$$T_b=\frac{an}{20}\times b$$

$$T_c=\frac{anb}{20}\times\frac{60}{60-c}.$$

Steps in Design

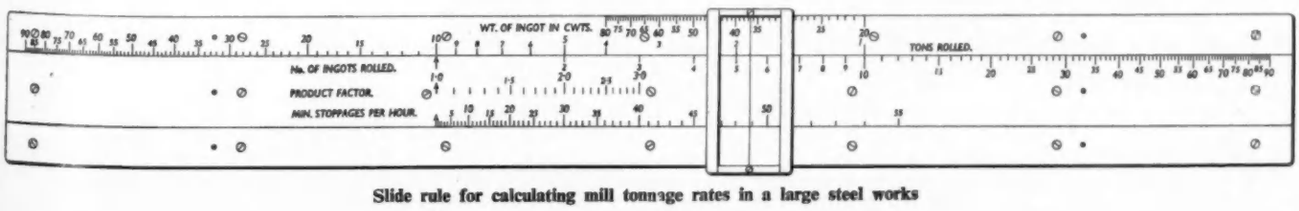
1. The first step was to decide, if there were to be some sort of semi-mechanical aid for the works clerk, whether it should be a nomograph or a special slide-rule. It was decided to have a slide-rule because it should be possible to design a multi-stage rule with a rigid procedure or drill, giving no choice of alternative at any point, and having complete separation of the three stages, with separate answers for T, T_b and T_c, yet making the calculation continuous, not three separate multiplications. It was felt, and this may have been prejudice, that a multi-stage nomograph would tend to be subject to cumulative error, and be more difficult to use for a non-mathemetical clerk than a slide-rule with a definite "drill." As the calculation is made many times a day, and every working day, the greater cost of the special slide-rule was not considered to outweigh its probable advantages.

2. Having decided on the slide-rule, the next step was to decide, using the logarithmic method of multiplication of the ordinary engineer's slide-rule, whether the multiplication should be "direct" or "inverse." This may seem rather a trivial point, but was one of a long series of decisions relating to making the rule as error-proof as possible, the general aim being that the operator should have at all times one course of action, and one only to follow. Every engineer is familiar with the fact that with "direct" multiplication, i.e. if one is multiplying A by B, setting "1" on the slide opposite "A," and reading the answer "AB" on the fixed scale under "B" on the slide, one is faced with the choice as to which end of the slide to use so that the answer is, in fact, available and not off the rule in thin air. If, however, one uses "inverse" multiplication, by setting "A" on the fixed rule under "B" on the inverse rule on the slide, the answer is always given on the fixed part of the rule under the only "1" on the slide that is available for the purpose.

Since with "inverse" multiplication there is no choice of action, "inverse" multiplication was adopted.

3. The next problem was how to provide three successive multiplications as a continuous operation, in which the intermediate answers would be available but need not be written down if not desired.

The first suggestion was to have two or



Slide rule for calculating mill tonnage rates in a large steel works

Technical Contributors Section (*continued*)

more slides, start at the top and proceed across the slides to the final answer. This suggestion was, however, found not to work very well in practice. Experimental rules were made of cardboard, plywood, &c., but in all cases the coefficient of friction was the enemy. Either the slides were too stiff in relation to each other and the fixed part of the rule, or they were too slack, and it seemed impossible within reasonable limits of expense to make a rule with more than one slide.

Since the use of one slide only seemed to be indicated, a cursor would be necessary, and in the event the cursor solved the problem of holding intermediate answers without having to write them down.

4. Having decided on inverse multiplication, a single slide and a cursor, it now became possible to proceed with the design of the actual rule, as illustrated.

It will be recalled that the first calculation is to give the " raw " tons of rail rolled per hour which is

$$T=\frac{a}{20}\times n,$$

where a is the weight of ingot in hundredweights, and n is the number of ingots rolled in an hour. By using the cursor it was possible to " build in " the conversion of ingot weights from hundredweights to tons by suitably marking the top scale, of ingot weights. It will be seen from the illustration that this scale is marked off in hundredweights but corresponds to the scale of tons rolled, immediately below, and it will be noted that both of these scales show values ascending from right to left.

The top scale on the slide is " No. of ingots rolled," and is in whole numbers, since half ingots are not rolled, from " 1 " to " 90," ascending from left to right.

The first operation is, then, to set the cursor line over the weight of ingot being rolled, move the slide until the number of ingots being rolled comes under the cursor line, and move the cursor to the " fiducial " arrow on the slide, above which will be found on the " tons rolled " scale, the " raw " tonnage rolled in the hour.

The next operation is to multiply the " raw " tons per hour by the product factor. This is done by leaving the cursor over the " raw " tons per hour, moving the slide until the appropriate product factor comes under the cursor line, and then moving the cursor to the left (if the factor is other than 1·0) until it is again over the fiducial arrow, above which will be found the tons rolled per hour corrected for the product rolled.

The final step is to make the allowance for mill stoppages in the hour. This calculation is to multiply the tons per hour corrected for product by

$$\frac{60}{60-c}$$

but again the operation has been simplified and made direct by setting out the " stoppage " scale in minutes stoppages per hour. As has been said, the assumption is that the mill would have worked at the same rate if the stoppages had not occurred, so that for instance, if the mill had been stopped from ten minutes or $^1/_6$ hour, the rate for the remaining fifty minutes or $^5/_6$ hour is multiplied by $^6/_5$=1·2. It will be observed that " 10 (minutes) " on the " Stoppage " scale is immediately below " 1·2 " on the product factor scale.

The calculation is now complete, and takes much less time to carry out on the actual slide-rule than to describe, a typical time being thirty seconds.

5. Although the general design of the slide-rule had now been thought out, there were a number of points which may seem to be details but which actually were important to decide.

It has been stressed that one of the main objectives was to make choice of action unnecessary at any stage in the operation. This had an effect on the length of scales to be used. The engineer using a standard slide-rule has become so used to putting in his own decimal points that he reads a number almost subconsciously as, say, 3, 30, 300, 0·3, 0·03, &c. In a special rule of the kind under discussion, however, this is undesirable. If the scale ranges from 1 to 90, as it does for " No. of Ingots Rolled," and " Tons Rolled," there must be no choice of reading, and a scale must be provided giving from " 1 " to " 90," in other words the scale must give two cycles, corresponding to two cycle logarithmic graph paper which provides the same facility.

A two-cycle slide-rule using the usual 10in base per cycle would have meant having an inordinately long rule because one would have to allow for the left-hand end of the slide being opposite the right-hand end of the fixed portion, 40in in total length.

A general principle in the design of scales is that accuracy beyond that required in normal practice is unnecessary. In this case weights of ingots are given to the nearest hundredweight and the " tons rolled " are required to the nearest ton. It was therefore possible to design the scales with these requirements in view and so long as clear and definite readings could be made to this degree of accuracy all would be well. After some experiment it was found that a modulus of 7½in would give the required clarity of reading without calling for an unduly long slide-rule, and this was adopted.

In order to avoid too much movement of the slide when the rule came into use, it was placed, as will be seen on the diagram, so that the fiducial arrows (and " 1·0 " of the Product Factor) normally lie under " 10 " on the " Tons Rolled " scale.

6. Finally, the slide-rule having taken shape, it had to be decided how and of what it was to be made. The rather unusual but, in the event, satisfactory decision was made to approach a manufacturer of precision steel rules, and the slide-rule was accordingly made by that company in stainless steel to their usual standards of accuracy from a master drawing. It may seem strange to have adopted such a heavy material as stainless steel. The rule was, however, to be permanently in a suitable box on the desk of the clerk who was to use it, and it was hoped that being made to tool-room accuracy and with first-class engraving, it would be easy to use since the slide would move freely, yet not too freely, and be easy to read. Time has proved that these predictions were correct. The slide-rule was designed and made in 1949 ; it is still in use, and at the time of the designer's last visit to the steel works, by the same clerk.

Recapitulations

The steps in the design were :

1. Whether to use a nomograph or a slide-rule. In spite of the cheapness and speed of construction possible for a nomograph it was decided to have a slide-rule mainly because it was thought it could be made more error-proof.

2. Inverse multiplication was adopted to avoid the possibility of alternative settings.

3. The problems incidental to a triple multiplication to be carried out as one continuous calculation were solved by the use of a single slide having three scales and a cursor.

4. Two conversions, from hundredweights to tons and from minutes of stoppage to the appropriate stoppage conversion factor, were built into the respective scales, reducing the complexity and time of the calculation.

5. In order further to avoid any alternatives in procedure, and in particular any worry as to whether a number is " 2 " or " 20 ", " 6 " or " 60," &c., the scales were made two cycles in length, e.g. from " 1 " to " 90."

6. The scales were designed only to the degree of accuracy required. For instance, the product factors used are " 1·0," " 1·1," " 1·2," &c., up to " 3·0." It was neither necessary nor desirable to have readings on the scale to " 1·05," " 1·15," &c.

7. A modulus of 7½in was adopted to give adequate clarity without undue overall length.

8. Because it was to rest permanently on a desk, the slide-rule was made of stainless steel to tool-room standards of manufacture and engraving.

Tyre Efficiency

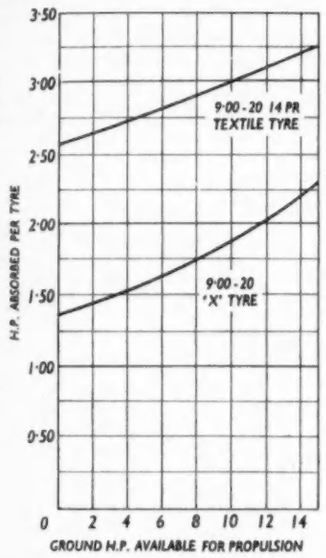
A large number of measurements have recently been made to demonstrate that the power dissipation of vehicle tyres is subject to control by the tyre designer to an extent sufficient significantly to affect operating costs. The results, and the thinking behind the experiments, are presented below.

THE tyred wheel consumes energy as it rolls, as is made evident by the increases in temperature and inflation pressure which become obtrusive when the speed is high or the heat losses to the atmosphere are low. The major mechanisms of energy dissipation in the conventional tyre are three in number :

(1) The side walls flex through one cycle per revolution; the plurality of plies forms a beam which resists this flexure, and the stresses that result are sufficient to give rise to hysteresis losses.

(2) Since the cords of the conventional tyre are laid on the bias, compression of the casing causes one layer of cords to turn relative to its neighbour(s)—imagine a lazy-tongs mechanism—and this imposes shear stresses on the intervening rubber, again evoking hysteresis.

(3) As the crown of the tyre comes in contact with the ground it is bent from a curved to a flat section ; since the flexural axis will be near to the casing plies, this causes a large compression of the tread, and the outer surface is, therefore, rubbed over the ground in a direction towards the plane of symmetry in the front of the contact patch and away from it in the rear.



Maximum load and inflation pressure. Road speed 18·7 m.p.h.

Power consumption of pneumatic tyres

Of these three mechanisms it is clear that the first and second evolve heat within the carcass of the tyre, whence it can only with difficulty be removed because the materials of construction are poor conductors. The third liberates heat at the face of the tread, where it is easily dissipated to the atmosphere, but in addition has the effect of abrading the rubber of the tread.

All of these mechanisms can be seen to be much reduced in a tyre of radial cord construction with a stabilised tread :

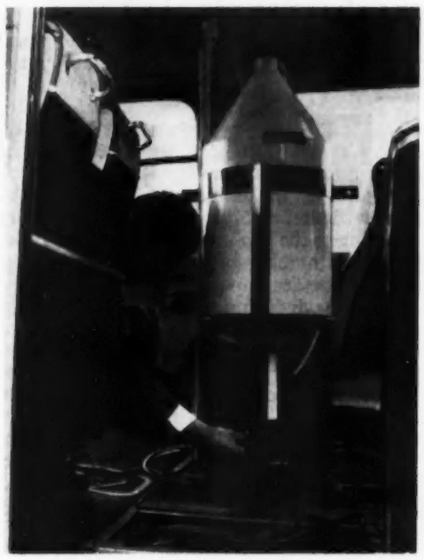
(1) Only one steel or two textile layers of cord will be necessary, so that the strain energy of the side wall will be drastically reduced.

(2) This effect does not exist between the radial cords, and is virtually absent in the stabilised tread due to its greatly enhanced stiffness compared to the side walls.

(3) The stabilised tread is capable of resisting the tendency for the inflation pressure to distort it from a cylindrical to a toroidal surface, and therefore relative motion between tread and ground is suppressed.

The construction of such tyres is, of course, the subject of patents possessed by the parent company of the Michelin Tyre Company, Ltd., and accordingly that firm has investigated these effects and their influence upon the performance realised in service. An example of the magnitude of these differences is afforded by the graph reproduced here, which shows the power dissipation of a tyre rolling on an effectively rigid drum. The difference between the two tyres would, for an " eight-wheeler " with twelve such tyres, correspond to a saving of 37 per cent on the 32 h.p. needed to drive it at 20 m.p.h. (or 35 per cent of 31 h.p., assuming double drive with no recirculation of power). The rather large programme of experiments needed to develop a relation giving power dissipation for all speeds, loads, and transmitted powers has not, we are advised, been undertaken, despite the need for a reliable formula for performance calculation.

The company has, however, validated the significance of these effects in service by an extensive series of strict comparisons performed under the surveillance of independent bodies (the Royal Automobile Club in the case of experiments in this country). Each test was conducted with a pair of vehicles of the same design and with two sets of tyres, one comprising conventional tyres of a brand specified as original equipment on the vehicle, and the other Michelin " X." The two vehicles were fitted with graduated fuel tanks provided with sight glasses, and the tanks filled with an accurately weighed quantity of fuel. The two vehicles were then sent out together to run until the measured quantity of fuel was exhausted : the route was so arranged that this would occur when the engines were under load and not when running down a gradient. The mileage achieved was measured on a calibrated speedometer in a third vehicle accompanying the subject vehicles. Naturally, the level in the tank could not be observed accurately with the vehicle moving, so subsequently fuel was added to or removed from the test tank to bring the level exactly to the required point above which it had been filled, and the total mileage covered was corrected accordingly. Then the tyres (and wheels) of the two vehicles were exchanged, keeping their same positions—e.g. inner offside rear to inner offside rear—and the test repeated, with the same drivers in each vehicle and the same routes, though normally on the following day. In each of the two runs, the vehicle on " X " tyres followed the vehicle on o.e. tyres, partly for



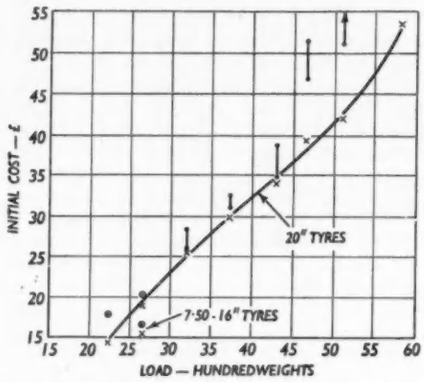
The test tank used in the exact method : opposite the " zero " of the sight tube the tank is of a reduced diameter

Changing wheels in between runs in a demonstration : notice the large glass test tank above the tailboard of the nearer " Trader "

the practical reason that the former could more easily keep up with the latter than *vice versa*, and partly in order to render the comparison unfavourable rather than otherwise to the "X" tyre; because of this arrangement, the results represent a case intermediate between keeping the performance the same and taking advantage of the enhanced efficiency entirely in fuel economy (as might occur in a duty in which the engine was running mainly on the governor) and the other extreme of using the power made available to do the same work more quickly. That there was a difference in the parasitic power losses was reported both by the drivers, who found it easy rather than, as usual, difficult to keep up, and by the observers in the third vehicle, who would see the vehicle on "X" tyres braking more often. The results were then derived by adding up the distances run by each set of tyres on the two different vehicles and expressed as the difference divided by the greater figure, i.e. the economy caused by changing to the less wasteful tyre. The results of a large number of these comparisons are given in the accompanying Table.

These savings are regarded by Michelin as significant: it is pointed out that for a tanker averaging 10 m.p.g. and using tyres purchased at £28 each, a saving of 6 per cent on fuel at 3s. 6d. per gallon is equivalent to a discount of 18½ per cent on the cost of tyres. For a vehicle less costly in tyre maintenance, such as the Ford "Anglia," a saving of 12 per cent (see below) would cover the whole of the tyre costs!

The tests recorded in the Table were, as mentioned above, all observed by competent authorities, but notwithstanding this the Michelin Tyre Company, Ltd., last week staged a demonstration in the presence of the Press. Three pairs of vehicles were used, namely Ford "Anglia" 105E cars, Morris 1-ton vans, and Thames "Trader" 4-D 5-ton trucks; the original equipment tyres, which had been procured by the R.A.C., varied widely, being respectively four-ply Firestone tubeless, Dunlop "Highway" tubeless, and Goodyear "Traction Himiler." To allow two runs to be made in the limited time available, the method of test was altered from measuring the distance run on a known quantity of fuel to measuring the fuel consumed on a selected circuit; each vehicle was fitted with a large test tank with



Purchase price and carrying capacity of giant tyres

a narrow neck, and having started with the tank exactly full had the tank refilled after the run from weighed containers. This method is clearly less accurate than the normal method, since it is affected by changes in the volume of the test tank and of the density of the fuel in the initial charge (although, because the day of the demonstration was consistently dry and overcast, these changes were probably negligible) but since the tests were intended merely to compare the fuel utilisations of two vehicles that were in the same environment at all times, these inaccuracies can hardly affect the results. The principle of changing the tyres between vehicles was followed as in the exact method described above; the drivers were drawn from the Army M.T. School, and their method of driving was described as "uniform." The saving in fuel effected by the Michelin "X" tyres measured over two 65-mile circuits was, for the "Anglia," 12·2 per cent, for the Morris van 5·7 per cent, and for the Thames "Trader" 14·1 per cent.

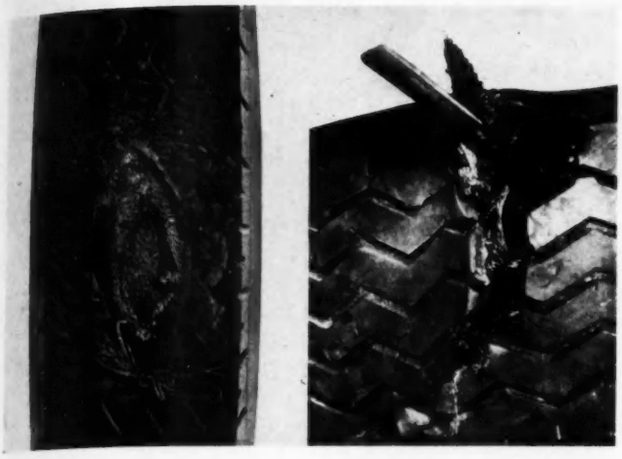
It will have been noticed that the Michelin Tyre Company has made no attempt whatever to distinguish or explain variations in efficiency among conventional tyres, but has merely shown that the "X" has a large or small superiority in this respect over all others. This presumption becomes, perhaps, acceptable when it is found that the company does provide evidence that the "X" tyre is not inferior in other respects. As an example, we have plotted herewith the list prices of "X" tyres on a base of rated load, and indicated also the range of prices of tyres of other manufacture; there is no suggestion that all tyres available on the market are included, but nevertheless it is clear that more costly tyres are offered for sale. It should perhaps be mentioned that the load-carrying capacities plotted on the graph are, for "X" tyres, valid up to a sustained speed of 60 m.p.h.

We availed ourselves of the opportunity presented by the demonstration to drive in quick succession two similar vehicles on conventional and on radial cord tyres. These were the two "Trader" 5-ton trucks with

Impression of an "X" tyre, showing which parts are replaced in the "RebuildeX" process. Observe that the cords of the casing lie in radial planes

4-D engines, that on original equipment tyres having done 6000 miles and that on "X" tyres about 30,000 miles. On the truck on o.e. tyres the steering felt excessively low geared, but nevertheless the minor irregularities on a well surfaced main road caused the wheel to kick fast and hard through our hands and the steering column to thrash fiercely; although the vehicle was fully loaded, the ride was not really enjoyable. On the older vehicle there was virtually no kick at the wheel, the steering column was perfectly still, and the ride seemed quiet and comfortable. Our impression was that the radial-cord tyre would

Date	Make and type	Distance covered by vehicles, with equal amounts of fuel: when on original equipment tyres	Distance covered by vehicles, with equal amounts of fuel: when on Michelin "X" tyres	Extra distance on "X" tyres in percentage	Country where test carried out
	Cars	kms.	kms.		
November 8 and 9, 1960	2 CV Citroen	499·2	627·0	25·7	France
December 8 and 9, 1960	2 CV Citroen	582·5	671·6	15·3	Belgium
November 29 and 30, 1960	"Dauphine" Renault	736·6	820·6	11·26	France
November 15 and 16, 1960	PL17 Panhard	497·7	530·9	10·67	France
December 15 and 16, 1960	Fiat 600	500·1	563·8	12·74	Italy
February 28 and March 1, 1961	Giant	536·3	586·0	9·30	Italy
December 20 and 21, 1960	"Aronde" Simca	581·5	633·7	8·98	France
December 19 and 20, 1960	Fiat 1100	574·4	623·9	8·61	Italy
November 30 and December 1, 1960	403 Peugeot	616·8	668·1	8·33	Belgium
December 13 and 14, 1960	404 Peugeot	706·0	751·8	6·49	France
February 15 and 16, 1961	Ford Taunus	682·3	721·6	5·73	Germany
February 10 and 11, 1961	Volkswagen	585·2	646·6	10·6	Holland
December 15 and 16, 1960	Opel "Rekord"	562·2	607·4	8·04	Germany
January 25 and 26, 1961	Mercedes	533·6	590·1	8·87	France
April 6 and 7, 1961	Lancia "Appia"	734·7	795·4	8·26	Italy
March 14 and 15, 1961	Alfa-Romeo "Giulietta"	710·7	771·0	8·48	Italy
March 16 and 17, 1961	Volkwagen Export	593·2	638·5	7·54	Germany
February 8 and 9, 1961	403/7 Peugeot	537·2	590·4	9·91	France
April 6 and 7, 1961	"Ariane" Simca	709·4	755·4	6·48	France
		Miles	Miles		U.K.
December 16 and 17, 1960	Ford "Zephyr"	352·5	375·8	6·6	(15 gallons)
March 8 and 9, 1961	Ford "Anglia"	398·0	431·6	8·5	(10 gallons)
January 18 and 19, 1961	Vauxhall "Velox"	333·78	348·56	4·4	(13½ gallons)
March 22 and 23, 1961	Austin A.55	336·8	363·0	7·8	(12 gallons)
	Commercial Vehicles				
		kms.	kms.		
December 29 and 30, 1960	Volvo Z37507	509·7	563·4	10·53	Belgium
December 21 and 22, 1960	Scania Vabis L5534A	652·9	757·5	16·02	Holland
December 14 and 15, 1960	Leyland bus	606·1	669·8	10·51	Holland
January 25 and 26, 1961	D.A.F. A1600	596·3	680·3	14·1	Holland
January 30 and 31, 1961	Ford FK 1250	618·0	657·2	6·3	Holland
March 13 and 14, 1961	Opelblitz 1T9	536·9	604·2	12·5	Germany
March 21 and 22, 1961	Hanomag-Kurier 1T9	444·9	484·4	8·9	Germany
March 23 and 24, 1961	Mercedes 319 1T75	654·1	763·6	15·08	Germany
March 27 and 28, 1961	Fiat 682	593·3	645·9	8·87	Italy
April 6 and 7, 1961	Peugeot 850 kgs	701·2	732·4	4·45	France
April 4 and 5, 1961	Mercedes LPS 133	557·2	627·1	12·66	Germany
October 8 and 9, 1960	Berliet GLM BD	465·7	504·2	8·28	France
March 2 and 3, 1960	VW Kombi (bus)	523·1	568·1	8·60	Germany
		miles	miles		U.K.
February 15 and 16, 1961	Thames "Trader" 7-ton	252·2	291·57	15·6	(19 gallons)
February 22 and 23, 1961	Commer 5-ton	271·0	313·1	15·5	(16 gallons)
March 16 and 17, 1961	Leyland-Bedford coach	291·1	322·9	10·9	(18 gallons)
March 28 and 29, 1961	Leyland "Comet"	292·5	328·2	12·2	(25 gallons)
April 10 and 11, 1961	Morris 1-ton	326·6	344·6	5·5	(14 gallons)
April 12 and 13, 1961	A.E.C. "Mammoth Major"	221·4	248·6	12·29	(28 gallons)



Two examples of severely damaged tyres which proved repairable

appeal even more dramatically to the driver than to the owner of the vehicle.

In the past the "X" tyre has suffered from the disadvantage that when it was worn out it could not be retreaded and, since it cannot be cut up, it was extremely difficult to scrap. There has, however, been introduced a process called "RebuildeX" for renovating "X" tyres in the giant (all-steel) sizes. As is suggested by our impression, the entire tread, steel and rubber together, is renewed; the replacement of the steel, as distinct from a mere recapping, is insisted upon, since cuts in the rubber may allow moisture to reach and corrode the metal, and the only way to detect such aggression is to radiograph the entire tread area. The ability to replace only part of the strength members is, of course, not possessed by any tyres but the "X," similar tyres built under licence from Michelin, and, obviously, tyres with detachable treads; it allows the reconditioning of tyres that have been damaged extremely badly—see the examples illustrated. Because the cords of a single ply tyre are not woven together, it is possible for the cover to be badly torn without the individual cords being severed, so that "RebuildeX" can be applied to tyres with gross punctures such as are seen in the last illustration. Even when the casing cords are damaged or ruptured the casing can be repaired provided the damage lies beyond (radially) the inner one-third of the side wall and does not extend more than 4in.; the repair scheme is to apply a patch with the cords parallel to those of the casing. The capability of this reconditioning process is so great that Michelin recommends that all "X" giants, however badly worn or damaged, should be returned to the firm for examination. Only the firm can pronounce them irreparable.

Generator Busbars for Komati Power Station

ALUMINIUM TO BE ADOPTED

Aluminium sections are being used for the 100MW generator busbars to be installed at Komati power station under construction in the Eastern Transvaal. The busbar installation, consisting of four zones, partly of double-channel section and partly of various tubular sections, with flexible connectors, porcelain insulators, and screening are briefly described and illustrated. Reference is made to tests conducted at the Chelmsford testing station of Crompton Parkinson, Ltd.

LAST week we saw a 100MW aluminium busbar assembly being tested at the works of Crompton Parkinson, Ltd., Chelmsford, Essex. The busbars will later be shipped to South Africa for installation in the new Komati steam power station which is being built in the Transvaal by ESCOM (the Electricity Supply Commission of South Africa). It will be the first time that ESCOM has used aluminium busbars between the generators and the main and unit transformers. The principal advantages gained from the use of aluminium instead of copper are in weight and cost and in the smaller number of joints required.

When the station (see Table I) is completed it will have a generating capacity of over 1000MW. The site is 5300ft above sea level, the atmosphere is dry and dusty, and ambient temperatures vary between 14 deg. and 95 deg. Fah., the maximum being 104 deg. Fah. The first two generating sets, which are being built by A.E.G., Germany, are of 100MW each and will be commissioned towards the end of this year. Details of the generating set, the generator transformer and the unit transformer are tabulated below. Each generator is earthed through a 5kVA neutral earthing transformer, having an equivalent resistance of 3000 ohms at the rated voltage of the generator. The h.v. neutral of the main transformer and the l.v. neutral of the unit transformer are solidly earthed. The fault capacity on the outgoing side of the main transformer is 12,500MVA at 275kV.

The contract for the supply of the first two busbars, one for each generator transformer unit, was placed with Hubert Davies and Co., Ltd., Johannesburg, which submitted a quotation in co-operation with Alcan Aluminium of South Africa, Ltd. Design and fabrication of the busbars were carried out in Canada by the Aluminium Company of Canada, Ltd., making use of the experience and plant which this company has applied to the manufacture of aluminium busbars installed for its own generating stations, totalling 3000MW capacity, including sets up to 150MW.

It was decided in December, 1960, that testing of the busbars could be done most expediently and cheaply in England. Accordingly, it was arranged that the tests should be done at the Short Circuit Testing Station of Crompton Parkinson, Ltd., Chelmsford. This decision created an urgent requirement for a set of screening to be manufactured in

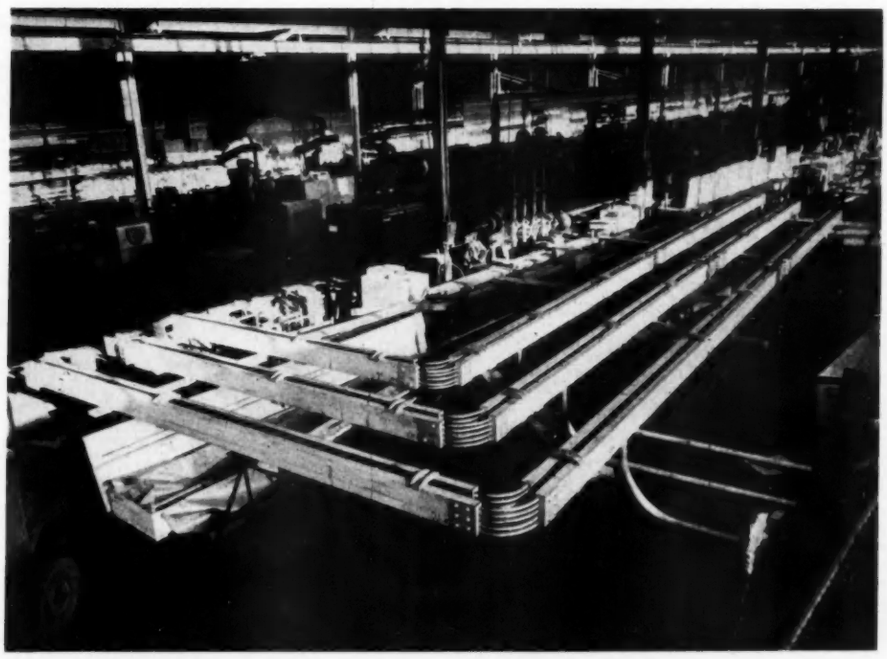


Fig. 1—Generator busbars of aluminium for Komati power station, South Africa. The generator end is on the left; the generator-transformer end on the right (background); the unit transformer connections right

England. Alcan Industries, Ltd., was able to supply all the necessary materials: the complete 3½-ton screening structure was then completed and delivered under contract by G. and E. Engineering, Ltd., Clapham, London, before the scheduled date of March 27.

The busbar equipment is specified to comply with B.S.159 "Busbar and Busbar Connections," and B.S.2817 "Enclosure of Electrical Parts." The installation is made of various sections of D.50S alloy (a magnesium silicide alloy of closely controlled composition), with a minimum U.T.S. of 29,000 lb per square inch and a minimum conductivity of 55 per cent I.A.C.S. Details of the installation and of the test requirements are given in Tables II and III.

The busbar installation is loaded in four zones, designated A, B, C, D in Table III. A factory assembly of zone A, which is in three sections, is shown in Fig. 1. Zone A1 (approximately 13ft long) is on the left of the picture and at right angles to it are zone A2 (about 19ft 8in long) and beyond that zone A3 (about 23ft long). In the foreground of the picture, near the right-angled junction of zones A1 and A2, one can see the connection to the 3in diameter tubular sections which will make up zone C of busbar to the unit transformer; zone D, consisting of 2in tubular sections, will be connected to the l.t. (i.e. 6·6kV) winding of the unit transformer. Part of the 10·75in tubular sections that will make up zone C, to the generator transformer can be seen, connected to the far end of the zone A3 bars, on the extreme right of the picture (Fig. 1). The stranded aluminium connectors between the double-channel sections and the 10·75 in tubular busbar sections are illustrated in Fig. 2. Similar flexible connectors are fitted in the double-channel section, as shown in Fig. 5, to allow for expansion.

The double-channel busbars are shown set up for testing in Fig. 3. A general view of the installation in the test area at Chelmsford is given in Fig. 4. Test conditions for the temperature run and for the application of short time current, to simulate fault conditions, are given in Table III. In the temperature run a current of 6600A sustained for several hours would exceed the capacity of the testing station. Accordingly, approval has been given to extrapolate the temperature rise at full current from a series

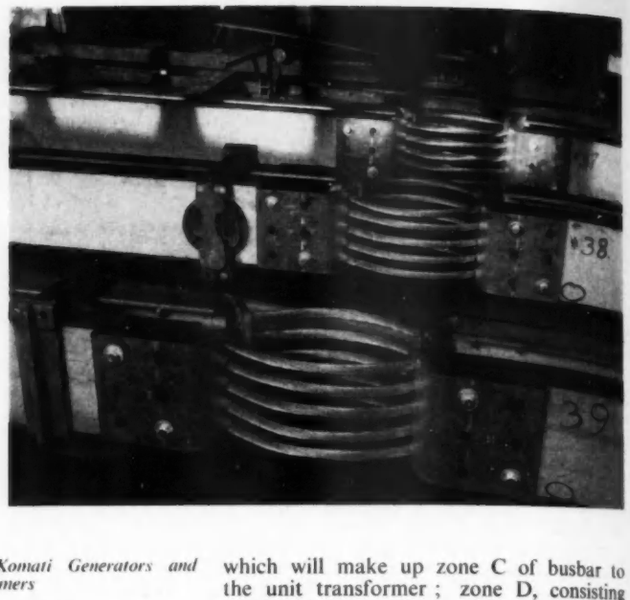


Fig. 5—Expansion connectors in the 10in. double channel busbars. The insulator supports can also be seen

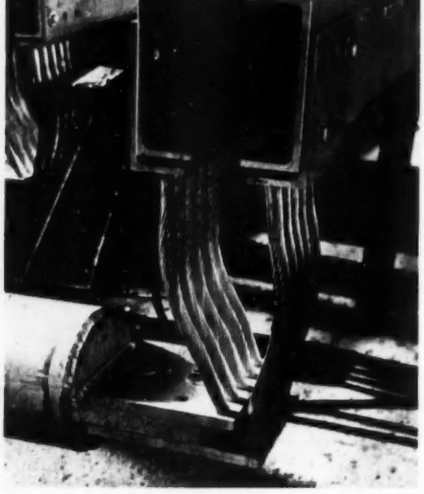


Fig. 2—Connectors linking the 10in channel to the 10in tube in the generator busbars at Komati

TABLE I—*Particulars of Komati Generators and Transformers*

Generator :	
Maker	A.E.G., Germany
Rated capacity	111·1MVA
Reactance (sub-transient)	17 per cent at 111·1 MVA
Normal rated current	6100A
Normal rated voltage	10·5kV
Connection	Star
Generator Transformer :	
Maker	A.S.E.A., Sweden
Rated capacity	110MVA
Reactance	12·3 per cent at 110MVA
Primary normal current	6050A
Voltage ratio (l.v./h.v.)	10·5kV/300kV
Connections (l.v./h.v.)	Delta/Star
Unit Transformer :	
Maker	Ansaldo-San Giorgio, Italy
Rated capacity	10MVA
Reactance	7 per cent at 10MVA
Normal current :	
Primary	525A
Secondary	875A
Voltage ratio (h.v./l.v.)	10·5kV/6·9kV
Connections (l.v./h.v.)	Star/Star
Current Limiting Resistances :	
Maximum fault level after limiting resistance	100MVA

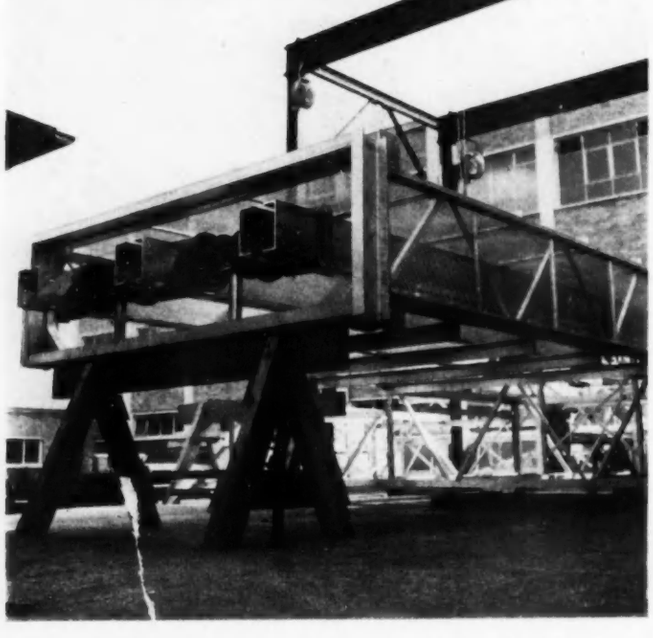


Fig. 3—Double-channel busbars set up for test at Crompton Parkinson's testing station, Chelmsford

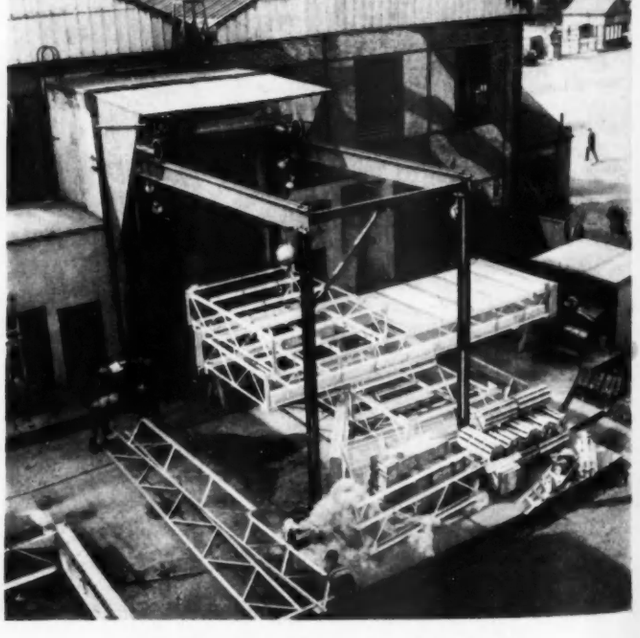


Fig. 4—Erecting busbars for test at Chelmsford

TABLE II—*Busbar Insulation Specification*

Type	Air
Minimum phase-to-phase clearance	
11kV busbars	9½in
Minimum phase to earth clearance	
11kV busbars	5½in
Minimum insulator creepage distance	
11kV busbars :	
Indoor	8in
Outdoor	15in
6·6kV busbars	9in
Minimum impulse withstand test voltage at sea level (1/50 or 1½/40 microsec full wave) :	
11kV busbars :	
Indoor	160kV crest
Outdoor	160kV crest
6·6kV busbars	80kV crest
Minimum 60 sec., 50 cycle, wet withstand test voltage at sea level :	
11kV outdoor busbars	55kV r.m.s.
6·6kV busbars	35kV r.m.s.

of tests carried out at currents up to about 3000A or as high as the impedances will allow. These results will be confirmed by calculation and by tests on site under full load conditions.

In the fault current tests a current of 82,000A for three seconds would also be above the capacity of the testing station. However, an equivalent test in accordance with paragraph 22 and appendix F of B.S. 159 is permissible. An estimated current of 62,000A is available. During these fault tests the electro-mechanical loading induced in the busbars of zone C is calculated to be 736 lb per foot run. A 70 per cent d.c. component is specified on the centre phase at the instant of short circuit.

Power-frequency voltage tests are also carried out in accordance with B.S. 159, clause 24, by the application of 35kV, r.m.s., to zone D and 55kV, r.m.s., to zones A, B and C, for one minute duration in each case.

The main companies that contributed to the busbar installation are as follows : aluminium busbar components, Alcan Aluminium of South Africa, Ltd. ; design and fabrication, Aluminium Company of Canada, Ltd. ; supply of aluminium materials in the United Kingdom, Alcan Industries, Ltd., Banbury and London ; manufacture, in South Africa, of screening for No. 1 set, J. Alers Hankey, Ltd., Johannesburg ; manufacture, in England, of screening for No. 2 set, G. and E. Engineering, Ltd., Clapham ; manufacture of all porcelain insulators, Stealite and Porcelain Products, Ltd., Stomport.

TABLE III—*Physical Particulars and Ratings of Busbars*

Zone	Material (All DSOS alloy)	Weight lb/foot run	Current ratings for test, Amperes		Impedances at rated loads	Estimated resistances at 20 deg. Cent.,
			Normal*	Fault†	microhms/ft	microhms/ft
A	10in by 3in double-channel Alkan shape 91018	2 × 8·56 = 17·12	6600	46,100 for 3 sec.	42	1·015
B	10·75in o.d. by ½in wall tube	18·87	6260	46,100 for 3 sec.	46	0·92
C	3in standard pipe size	2·617	1520	82,100 for 3 sec.‡	62	6·63
D	2in standard pipe size	1·262	1080	12,000 for 3 sec.	70	13·76

* 30 deg. Cent. rise permitted. † 300 deg. Cent. rise permitted. ‡ Or equivalent I^2t

Development of the Iron and Steel Industry

AMONG the statutory obligations of the Iron and Steel Board is that of reviewing the productive capacity of the industry, and ensuring its adequacy to meet demand. This is kept under constant review, and from time to time the Board issues special reports on its findings. The third of these reports, entitled "Development in the Iron and Steel Industry, Special Report, 1961," has just been presented to Parliament. It covers the period to 1965, as well as taking a forward look in a general way to 1970.

The Board believes that the expansion of the iron and steel industry ought to be sufficient to meet the requirements of a more rapid economic growth than there has been in recent years. A reasonably optimistic assumption is that in 1965 the crude steel requirement will be in the region of 23,250,000 to 23,500,000 tons for home and 5,250,000 tons for export, and a total figure of 32,000,000 tons is likely to be adequate to cover contingencies. An estimate of capacity has been made by the industry, and the interesting fact emerges that by 1965 the British iron and steel industry should be able, for the first time for many years, to meet all home demands and have a surplus for export. In fact, taking present production capacity and adding the amount necessary to cover schemes for new plant at present in hand or under active consideration, the industry's capacity would, by 1965, be well above the figure estimated as necessary. However, present capacity includes some 2,500,000 tons from plant which may well be uneconomic by 1965 and should go out of production as soon as the newer and more efficient plant comes into operation.

The overall picture, therefore, is of an industry which will not only be able to meet in full the estimated home and export demand, but will do so with modern and efficient plant. This will be of vital importance, especially in view of certain other facts detailed by the report. If the industry is to operate competitively, it must be assured that its costs can be kept under proper control, and the Board stresses the importance of purchased material costs—particularly that of coal. More fuel is used by the iron and steel industry than by any other manufacturing industry in the United Kingdom—in recent years it has accounted for over 11 per cent of the total national fuel consumption. By far the greatest single item in the fuel account is coal, on which some £100 million are spent annually. It is therefore, on coal costs that the future competitive ability of the British iron and steel industry largely depends.

Technical developments are helping in the matter of fuel costs. Larger blast-furnaces, full burden preparation and other technical changes have reduced the coke rate (coke consumption per ton of iron produced) and this is of considerable help in reducing the total fuel costs. In the steel works the growth of the electric steelmaking technique has resulted in overall fuel economies, and the use of oxygen steelmaking processes, which is growing rapidly, is another important factor in the fight to reduce fuel costs. The newer oxygen steelmaking processes do not use any fuel at all, though the capital plant is costly and the oxygen has to be paid for. However, all the efforts being made to reduce fuel consumption, important and successful though they are, cannot provide the full answer to the problem, which is one largely outside the industry's control. The Board therefore attaches very great importance to the need for coal at a competitive price.

Assuming that costs can be kept under control, the picture of the industry in a position to meet all demands made upon it is an interesting one, and encouraging for consumers and the country's economic welfare alike. But there is more to the question of efficient operation than simply that of raw material costs. In the past, because the industry could not regularly meet the demands upon it, large quantities of steel had to be imported. This was often uneconomic, but in the circumstances at the time it had to be done. Sometimes, though, a steel shortage developed artificially, when users were building up stocks larger than they needed because they were afraid of being left behind in the rush on the available supplies. Conversely, when demand slackened, stocks were drawn upon—stocks which had often cost more than they need—and the steel works were under employed. With the very large capital plant now needed, a steel works can only operate efficiently if it does so at optimum output, and it is to be hoped that the prospect of being able to get supplies as and when they are needed will persuade users to order regularly and realistically. This can only result in more efficient operation of the iron and steel works and will contribute nationally to price stability.

In the past the Board has had to be concerned largely with increasing the capacity of the industry but the position is now changing with the prospect of productive capacity meeting estimated demands. Expansion will be necessary in the future—provided, as already emphasised, that competitive ability can be maintained, but in future schemes more account will have to be taken of plant location. Many British iron and steel works were built in what is now an uneconomic position because at the time when they were built, ore and fuel were available locally. As the local raw materials became worked out, the works were at a disadvantage, but they continued in operation because of availability of markets or of labour. Some of these works have disappeared, other are still at work, and are likely to continued in operation. But the siting of new works is considered very carefully before the Board's consent, which is largely necessary, is given.

Future large-scale developments are therefore likely to take place in areas where the economic advantages predominate, and this may mean that they will be sited where iron and steelmaking have never been undertaken before. An example of this economic siting is provided by the new Spencer Works of Richard Thomas and Baldwins, Ltd., which is now partly completed. This is one of the best sited works in the country. It is on land which is of little use for any other purpose, near to a seaport which can take quite large ships, reasonably near to its main markets and to supplies of coal and home-produced ore and near to a source of suitable labour. This will be the prototype for future large-scale developments.

LETTERS AND LITERATURE

Letters to the Editor

CLEAN AIR FOR CITY STREETS

SIR,—Whitehall is a good place to see the benefits that have already accrued from the Clean Air Act. Coal smoke has been eliminated from Government offices and the busy flow of shipping now passes up and down the Thames without visible smoke. Official measurements record a reduction in smoke and begin to show a decrease in sulphur dioxide. Old residents in Whitehall have noticed that nostrils, handkerchiefs and shirt cuffs are no longer blackened as rapidly as they were a decade ago. The propaganda of the National Society for Clean Air has thus borne welcome fruit.

But on the roads pollution seems to grow from ever more engine exhaust pipes. The unpleasant nuisance, and possible danger, of engine exhaust fumes in congested streets calls for a reappraisal of the location and direction of the pipes that emit these fumes. At the present time it is in the zone between knee and ankle that a man feels his trousers to be blasted by the exhaust from hard working engines, of buses and other vehicles that pass him as he stands on a city pavement. A mother of small children points out that that zone is exactly where the face of her child is when she seats it in a push chair. Male designers planned to emit the exhaust fumes at the rear on the offside, but with modern one way streets the offside is frequently the side nearest to the child on the pavement.

In one city in this country these horizontally emitted exhaust fumes were so regularly blasted right into the open doorway of a communal block of flats that popular protest caused a bus stop to be moved. Why did they not ask for the direction of the exhaust to be moved? By what right do vehicle owners and drivers thus assault with offensive jets of hot and noisome exhaust gases, people standing or walking on the pavements that are expressly made for the use of people?

Many vehicles already exhaust their gases upwards; diesel railcars, military vehicles, ambulances, U.D.C. refuse collecting vehicles and most U.S.A. heavy road freight vehicles to mention a few of them. In the case that causes so much complaint of black smoke from badly maintained diesel engines, or misused engines, vertical emission of the exhaust at or above roof level of the vehicle would take the objectionable black smoke further from our noses and out of the line of sight of drivers of passing vehicles.

Should it be suggested that roof top level emission of vehicle exhaust gases may be a nuisance to people on the top deck of double decker buses, one is entitled to reply that the near ground level horizontal emission of engine fumes is a proved nuisance and a road danger. Cases of drivers being enfeebled or overcome by inhaling the carbon monoxide emitted by their own engine, or by other vehicles in city road jams, will be minimised if all vehicles be made to point their engine exhausts in the direction that the hot gases must eventually take in order to disperse from the streets—upwards.

May I therefore beg prospective purchasers of fleets of heavy vehicles to ask for a memorandum as to the feasibility of installing vertical exhausts before they place orders for new vehicles that may be run in city streets. If only a few big users of road vehicles would give such a lead others would follow because we need not remain slaves to this pollution of our streets.

Vertical exhaust pipes can be fitted in neatly, with front-engined vehicles at the side furthest from the driver, with rear-engined vehicles at the side furthest from the pavement, and with underfloor-engine designs the exhaust can rise vertically at either side. From an enclosed engine compartment the vertical exhaust could be made to suck the cooling air through the radiator and entrain for exhaustion all the unwanted engine blow-back fumes and hot oil smells, emitting them upwards above the nose level of passengers.

The relatively hot and narrow metal exhaust pipe could be surrounded by an artistically shaped larger and cooler tube made perhaps of fibre glass. The annular space so formed could serve to exhaust engine fumes and smells, just as big ship funnels have multiple passages and functions. Recalling the clever use of exhaust steam in the smoke-box of the classic Stephenson locomotive, to draw the air through the fire, one wonders whether I.C. engine exhaust can be used to regulate the suction of air through its radiator and to disperse fumes upwards. If road vehicle designers are now asked to try their hardest to arrange for the vertical emission of the engine exhaust they will find, we may hope, that it permits both freedom from engine noise and smells for their users, and courtesy to pedestrians.

Sooner or later the Ministry of Transport may be forced to require roof top vertical emission of engine exhaust gases for all heavy lorries, coaches, service vehicles, and for as many private cars as possible. Any case against vertical exhaust is so far not proved. A large scale experiment with hundreds of vehicles is urgently needed, and encouragement from the Ministry of Transport.

T. H. TURNER

Derby,
March 27, 1961.

NUCLEAR POWER PLANT STEAM CONDITIONS

SIR,—Mr. W. Melville, writing in your issue of March 31, is certainly correct in thinking that fossil-fuel-fired superheaters would considerably enhance nuclear power station efficiency.

When I worked for the U.K.A.E.A. I tried to find why these superheaters were not used. After making various enquiries I came to the conclusion that someone in the A.E.A. was not prepared to admit that fossil fuels were in any way better than atomic energy. After all, such an admission might cause someone to look a bit more closely at the whole question of atomic energy economics, and they might come to the same conclusion as myself—that atomic energy is quite hopelessly uneconomic anyway and that the nuclear power programme is an appalling waste of money.

G. HAIGH,
M.A.(Cantab.), A.M.I.Mech.E.

Lymm,
Cheshire,
April 17, 1961.

NATIONAL WATER GRID

SIR,—I was glad to note in his further letter of April 7 that Mr. F. Newhouse is interested to probe further matters in relation to my project for a national water grid. The whole subject is full of uninvestigated topics. There are the different forms of grid, the relationship thereof to the supply authorities, the position of a grid as an extreme drought reserve, and the operation in connection therewith of existing reservoirs. The balancing effect of variable rainfall incidence over the several hill areas serving a grid is especially interesting as minimising the need for storage. There is the application of a grid to the artificial replenishment of aquifers, and to river conservation, and finally the important question of the scale of delivery to which a water grid should be planned.

My figure for this last, as Mr. Newhouse notes, is 2000 cusecs. This discharge has been assessed for me by Dr. H. L. Penman as meeting the irrigation needs of about 1000 square miles of the crops specially benefited by it during drought. It would not meet extreme peaks for which water would have to be drawn from previously recharged aquifers locally. So much as 2000 cusecs would not of course be continuously available in any upland area, but could only be drawn as available, in fairly wet spells, but it is the discharge figure which I put forward for discussion and investigation as the necessary rate to plan for, on the principle that a water grid must do its entire job.

This brings me to the point that irrigation is a great new demand, whereas those for public supply and industry are old, and the long established provision for which only needs supplementing, whilst irrigation service must apply not only to those lands, which it so happens, are alongside a stream, but equally to the far greater area of good land which is away from any stream. Hence it seems to me logical that grid planning should be centred on the irrigation demand, though with other demands as important annexes thereto. Therefore it is, I must maintain, extremely surprising that although the Great Ouse Hydrological Survey makes considerable reference to the increase of irrigation, the Working Party Report based on it and

the current Great Ouse Water Bill ignore the whole subject completely.

To deal with other points raised by Mr. Newhouse, the Grand Contour Canal would be constructionally on the one level, but with installations for inducing a variable flow, up to the maximum as stated above, and providing for the loss of head up to one foot, due to fall of the water surface as flowing. The arrangement of sector gates, as it might be, across the canal would not be the equivalent of introducing ordinary locks on the waterway: the method of passing traffic would be much simpler, though a matter for experiment. The "minor lifts" quoted by Mr. Newhouse from my earlier writings, would be barge lifts built to connect the Grand Contour Canal with some old waterway at a different level and of course to such size of vessel as the old waterway can take. The nine main terminal lifts, 310ft high, would, I agree, need very special design study.

Cardiff, J. F. POWNALL
April 15, 1961.

METROPOLITAN LINE WIDENING

SIR,—Mr. Kay in his letter published in THE ENGINEER of March 31 complains that London Transport's reply gave more than one reason why a four-track scheme has been used for the modernisation of the Metropolitan Line rather than the three-track scheme (with one track reversible) which he advocates. To single out one reason and ignore the rest in the reply would have been illogical and misleading, because in practice a number of different considerations all point the same way. With regard to Mr. Kay's other points, the three-track scheme would require one train, costing over £150,000, in addition to the thirty-one trains now needed; but that was only one of a number of reasons against the three-track scheme.

The possibility of giving emergency platform access to the fast tracks at the stations which will not be served by fast trains would not be a sound reason for adopting a three-track scheme which would be very much less satisfactory than a four-track scheme on a number of grounds. Platform access to the two new fast tracks could have been provided under a four-track scheme if desired; it was not provided because it was not considered necessary.

R. M. ROBBINS,
Chief Public Relations Officer
London Transport Executive,
April 18, 1961.

MOTOR VEHICLE NOISE MEASUREMENT

SIR,—I have read with interest the article by Robinson, Copeland and Rennie, on the above subject, in THE ENGINEER for March 31, 1961. I fear, however, that the reference to I.E.C. Document 29 (Central Office) 32, at the foot of the first column of page 495 may give rise to misunderstandings, as this is a working document restricted to I.E.C. National Committees and in any case is now superseded by the approved Recommendations. The correct reference is to "I.E.C. Publication 123: Recommendations for sound level meters." This publication can be purchased in the United Kingdom from the Sales Department of the British Standards Institution at 2, Park Street, London, W.1. You may be interested to know that all I.E.C. Publications can be obtained from the B.S.I., who are our United Kingdom sales agents.

L. RUPPERT,
General Secretary
International Electrotechnical Commission,
Geneva, Switzerland,
April 17, 1961.

MILLIONS TO BE SAVED ?

SIR,—In discussing the movement of passengers over relatively short distances on converted railways some of your recent correspondents have based their considerations upon the use of buses of forty seats capacity. May I suggest that this figure is too low ?

The cost of crewing is usually the largest single item of expense in public service vehicle operation to-day, and to offset its continual tendency to rise there is a strong incentive for operators to increase the carrying capacity of their vehicles. However, within the maximum permissible dimensions of 30ft by 8ft the ultimate has probably already been reached with the seventy-eight-seat double-deckers which are finding growing popularity. Upon converted railways the largest individual vehicles might be expected to have "plan" dimensions similar to those of railway vehicles, but have overall heights somewhat greater. By arranging for the road surface under structures to be only about 5in below the present ballast-top level nearly an additional foot of headroom would be gained, so making practicable the use of vehicles of 14ft overall height. This is a height several inches greater than that of many modern double-decked buses with conventional seating layouts, so that for journeys of medium duration on converted railways the use of double-decked vehicles should be entirely feasible.

Suburban passenger traffic might be particularly well catered for by articulated combinations, each consisting of a tractor unit and a double-decked semi-trailer. Within an overall length of 75ft these vehicles could each provide seating accommodation for some 150 passengers, to more spacious and comfortable standards than those customary today in either multiple-unit suburban trains or city buses. Not only should such vehicles be considerably more economical to operate per seat mile than present-day buses, but their carrying capacity per traffic lane would be higher. Only four vehicles per minute, for example, could pass 600 seated passengers per lane per minute—an exceptionally high figure by any road or rail standards.

P. J. SMITH
Potters Bar,
Middlesex,
April 4, 1961.

SIR,—In the past few months you have given column space to the views of people whose ideas and arguments would be more suited to the pages of *Punch* rather than those of a serious and responsible technical journal. I refer to the letters from the protagonists of railway conversion. The regress from the original proposal to the present wild fancies can only be described as bathos.

Any suggestion that the eminently controllable and efficient London underground railway system should be replaced by an extension of the free-for-all chaos of the surface roads is purely not worthy of space in a seriously intentioned journal. Brigadier Lloyd's ramblings about cruelty to live vehicles in your issue dated April 14 should surely have convinced all your reasonable readers that the aims of the Conversion League are not worthy even of consideration by any but the most fanciful or irresponsible.

B. KERSHAW
Manchester,
April 19, 1961.

SIR,—In the course of the correspondence on the conversion of railways into roadways a number of references have been made to traffic flows of the order of 1000 vehicles per hour and upwards on a single lane, and to headway between vehicles of under ten seconds. To those not accustomed to relating time, speed and distance in such a connection figures such as this may create a mental picture of dangerous congestion, it not being realised that for a flow of 1000 vehicles per hour at 60 m.p.h. the average interval between vehicles is 317ft (at 30 m.p.h. —158ft), or that at 60 m.p.h. a ten-second headway means an 880ft interval. You may perhaps consider it helpful to publish the attached table which was prepared

Flow (Vehicles per hour passing a given point)	Headway (in seconds)	Average interval in feet (nose to nose) between vehicles travelling along a single unimpeded traffic lane at varying speeds, flow rates and time headway.									
3,000	1·20	18	35	53	70	88	106	123	141	158	176
2,900	1·24	18	36	55	73	91	109	127	146	164	182
2,800	1·29	19	38	57	76	95	113	132	151	170	189
2,700	1·33	20	39	59	78	98	118	137	157	176	196
2,600	1·38	20	41	61	81	102	122	142	162	183	203
2,500	1·44	21	42	63	84	106	127	148	169	190	211
2,400	1·50	22	44	66	88	110	132	154	176	198	220
2,300	1·57	23	46	69	92	115	138	161	184	207	230
2,200	1·64	24	48	72	96	120	144	168	192	216	240
2,100	1·72	25	50	75	100	126	151	176	201	226	251
2,000	1·80	26	53	79	106	132	158	185	211	238	264
1,900	1·90	28	56	83	111	139	167	195	222	250	278
1,800	2·00	29	59	88	117	147	176	205	234	264	293
1,700	2·06	31	62	93	124	156	187	218	249	280	311
1,600	2·25	33	66	99	132	165	198	231	264	297	330
1,500	2·40	35	70	106	140	176	211	246	281	316	351
1,400	2·57	38	75	113	151	189	226	264	302	339	377
1,300	2·77	41	81	122	162	203	244	284	325	365	406
1,200	3·00	44	88	132	176	220	264	308	352	396	440
1,100	3·28	48	96	144	192	240	288	336	384	432	480
1,000	3·60	53	106	158	211	264	317	370	422	475	528
900	4·00	59	117	176	235	294	352	410	470	528	587
800	4·50	66	132	198	264	330	396	462	528	594	660
700	5·15	75	151	226	302	377	452	528	603	679	754
600	6·00	88	176	264	352	440	528	616	704	792	880
500	7·20	106	211	317	422	528	634	739	845	950	1056
400	9·00	132	264	396	528	660	792	924	1,056	1,188	1,320
300	12·00	176	352	528	704	880	1,056	1,232	1,408	1,584	1,760
200	18·00	264	528	792	1,056	1,320	1,584	1,848	2,112	2,376	2,640
100	36·00	528	1,056	1,584	2,112	2,640	3,168	3,696	4,224	4,752	5,280
Speed in m.p.h.		10	20	30	40	50	60	70	80	90	100

some time ago for the use of members of the Railway Conversion League.

M. J. DOUGLASS,
Hon. Co-ordinator
Railway Conversion League,
Guildford,
Surrey,
April 18, 1961.

SIR,—Mr. Walker's figures in your issue of April 14 appear to be somewhat awry and I would be grateful if you would allow me to provide the figures which we have obtained.

Expenditure by local authorities in 1957–58 on highways and bridges was £76,769,000 not £103,800,000. The cost of maintenance, improvement and new construction on roads by the central authority was £59,948,000. An extra £100 million seems to have crept in to Mr. Walker's figure. Even accepting your correspondent's remaining figures of costs and correcting the taxation figures—which are actually slightly less than those given—we arrive at a total of £393,717,000 instead of £526,800,000, and taxation figures of £399 million instead of £448,800,000.

However, if the cost of road accidents is to be included then motor insurance should be set against it which amounts to some £120 million a year. There is also purchase tax to be considered which, for the year ended March, 1959, amounted to £165 million. On these figures expenditure by road users is nearly £300 million in excess and not nearly £80,000,000 short as your correspondent suggests.

M. FRANCIS,
Information Officer
British Road Federation,
London, W.1,
April 19, 1961.

Book Reviews

Self-Organising Systems : Proceedings of an Interdisciplinary Conference. Edited by MARSHALL C. YOVITS AND SCOTT CAMERON. Pergamon Press, Ltd., Headington Hill Hall, Oxford. Price 60s.

AUTOMATA of the eighteenth and nineteenth centuries were aristocrats ; they were things to be looked at, not to be useful. Machines that did actual work were at first direct substitutes for muscle power. They could, for instance, push. But someone had to start them pushing and had to stop them pushing. According to legend, in 1713 a lad, Humphrey Potter, under the overwhelming drive of idleness, found that steam engines could control themselves. Provided that, in this case, you tied one end of a string to a valve and the other to some reciprocating part of the engine.

During the two and half centuries since then, the string has multiplied its ends and the things that they can be tied to have enormously increased. The former aristocratic automata have been reduced to the status of toys ; that was the only use for them. But during the past decade, roughly, technology has made possible devices that can respond to their external environment and internal state in ways that need not be laid down beforehand in detail and may be, in the current state of theory, unpredictable.

Thus the automation to be looked at, rather than to do a prescribed job, has come back, though not as an aristocrat. If it models anything, this will not be craftsman or musician or acrobat, but the humbler aspects of growth, recognition, adaptation and learning. Some may not model anything. They are built just to see how they behave.

In fact, modern technology forces us to reconsider and discover how much of various activities are essentially intelligent or biological, in some sense, and how much mechanical in the sense of being within the scope of current fabricated devices.

Automata, therefore, can be tools for studying these activities, as well as devices to which one can delegate a job during the lunch-hour. These activities lie in the fringes, sometimes lunatic, of many hitherto unrelated disciplines ; biology, psychology, mathematics, engineering, and sociology.

The Conference reported in this book was devised by the Information Systems Branch of the U.S. Office of Naval Research, together with the Armour Research Foundation, to concert the efforts of specialists in these fields. Held in Chicago in May, 1959, it used fourteen papers by invited speakers as foci for general discussion. These papers and the discussions are given in full, together with introductory remarks and addresses. The papers contain also references to cognate literature, and the book is well printed and illustrated. Absence of any index reduces its value very considerably, though the reduced value is still high.

The course of the discussions falls under four heads. The first, perception of the environment, deals with the awkward problems of what are meant by " organisation," " abstraction," " recognition " and the like. These, as are the other topics, are discussed from the experimental, theoretical, and technological points of view.

The second main head, effects of environmental feedback, largely concerns questions of adaptation and self-preservation. The third, learning in finite automata (that is, automata capable of only a finite number of distinct states), deals with attempts to achieve efficient " learning programs " that enable automata to improve their performance once started on a specific target, such as proving a theorem.

The final head, the structure of self-organising systems, tries to find elements and directives common or essential to systems that are generally regarded as behaving as if self-organising. Many plausible suggestions are made ; for instance Pask suggests that there must be some drive towards maximising the flow of some " currency," such as electric current, together with a counter-drive for economy. Likely requirements are elements that atrophy with disuse and are destroyed by overuse. But the whole topic bristles with sharp difficulties. Once you construct a system to evolve its own " purpose " it is difficult to detect that "purpose," even if there is one.

The significance of work like this is by no means academic. A " machine " is as hard to define as is a " mind." In practice it is the sort of thing we are used to calling a machine, and actions are mechanical if we are accustomed to seeing them done by machines. The most down-to-earth practising engineer to-day will accept as machines devices that do things that his father, or even he himself in boyhood, would have considered as essentially non-mechanical. To use machines effectively we must think deeply about their possible use as well as about their construction.

Whether one wishes to think deeply or no, and whether one can understand much or little in this book—no one would understand all the points of view represented—even random opening of it will disclose something that will amuse, surprise, or stimulate.

Structural Concrete. By K. BILLIG. Macmillan and Co., Ltd., St. Martin's Street, London, W.C.2. Price 84s.

THIS book is best summarised by reiterating a few words from the introduction that " its aim is to provide a minor encyclopedia on structural concrete." In its thousand pages it deals sometimes briefly, sometimes more lengthily, with most aspects of the use of concrete whether it be the properties of the materials or nuclear shielding. It deals with British, American and Continental codes of practice, although little reference is made to French practice, and it lists a large number of references at the end of each chapter. Perhaps the surprising thing about these lists is the omission of some of the more important references which exist in English. In attempting to cover the work and practice of many Continental engineers the author has sometimes left the reader with a hazy picture of British practice and, may be, the thought that Continental practice is of more importance. For instance, it is difficult to see why the major reference to hollow pot floors is to a DIN and why the only reference to prestressed concrete power-hammer foundations is French.

Nevertheless, Dr. Billig has collected together a remarkable collection of data from various authors and presented it in a readable form. It does give a good bird's-eye picture of the subject in all its aspects whether it be on materials, design or construction. It is not a critical book, but it does give sufficient information for one to know whether or not to seek for further information elsewhere. Parts could well have been omitted for clarity, but obviously the author like most people has more enthusiasm for certain parts of the subject rather than others. As an encyclopedia this excellently produced book meets the description quite adequately and it may be recommended as such.

The Physical Examination of Metals. Second edition. Edited by BRUCE CHALMERS and A. G. QUARRELL. Edward Arnold (Publishers), Ltd., 41, Maddox Street, London, W.1. Price 168s.

THE authors of this book when it was originally published in 1941 set out to draw the attention of metallurgists to many techniques that were at that time novel and not widely used but could provide information about the properties of metals and alloys. They described these techniques in simple terms, so that the underlying scientific principles could be understood by people for whom physics had only been a subsidiary subject.

Those two authors are now both professors of metallurgy ; Chalmers at Harvard University in the U.S.A., and Quarrell at the University of Sheffield. In this second edition of their book they have adopted the role of editors and enlisted the aid of seventeen colleagues in the rewriting and expanding of the book to meet changed conditions. During the twenty years since the first edition was being written, a generation of metallurgists has grown up with a much better appreciation of physical principles. Under these circumstances a completely new edition was necessary and this has been provided by the editors and their colleagues, who have used their specialised knowledge in the preparation of individual chapters. The authorship of each chapter is appropriately indicated in the contents list. From the following list of contributors it may be noted that seven of these authors have worked in British Government sponsored laboratories, seven teach in universities or colleges,

one of which is in Norway ; three work in well-known industrial laboratories, one of which is in the U.S.A.

CONTRIBUTORS

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The new edition has many illustrations and references. Its first 250 pages deal with optical, electrical, thermal and magnetic methods of observation, measurement and analysis. Then follow three chapters on x-ray, electron and neutron diffractions, one on electron metallography, and another on the radiation methods of pyrometry, and spectrographic analysis. Thus the first half of the book, in chapters one to nine, describes many techniques of great value to metallurgists, but probably quite outside the normal study of engineers. The reverse may be said of the latter half, where the subject matter of chapters ten to eighteen must interest engineers every bit as much as metallurgists.

Each author has assumed that the reader has no previous knowledge of the techniques being described but they carry the treatment of their subjects to a high level appropriate to modern conditions, and give examples of the ways in which individual techniques may be used. Chapters on the damping capacity of metals, and on measurements of elasticity using mechanical waves, introduce this latter part of the book and lead the reader logically and easily to six chapters on various practical methods of non-destructive testing. Engineers will find much of value in the sections on flaw detection by ultrasonic and ferrographic methods, magnetic methods of non-destructive testing, and magnetic methods of measuring the thickness of coatings ; and also in the applications of radioactive isotopes in metallurgy, and in micro-, and auto-, radiography. The final chapter, which discusses modern vacuum techniques, is followed by twenty pages of author and subject indexes.

This new revised edition is a helpful and well-nigh essential book of reference to all metallurgical libraries, laboratories and teaching establishments.

Technische Schwingungs Lehre. 2 Band —Scwinger von Mehreren Freiheitsgraden (Mehrläfige Schwinger). By KARL KLOTTER. Berlin–Göttingen–Heidelberg : Springer-Verlag, Berlin-Wilmersdorf, Heidelberger Platz 3. Price DM.58.50.

THE second volume of *Technische Schwingungslehre*, which now completes the work, deals with systems having several degrees of freedom. Although the subject matter is presented in very comprehensive detail, the book is intended to be a textbook rather than a work of reference, and its systematic development and careful selection of topics aims at enabling the reader, whether beginner or advanced student, independently to solve such new problems as he may come across. The first chapter accordingly is devoted to preliminaries, i.e. the equations of certain electromechanical analogies, while the second presents in detail, but in completely elementary fashion, free vibrations of systems with only two degrees of freedom. This gives occasion to consider already most of the phenomena which also characterises more complex systems. Free vibrations of such systems are discussed in the following chapter, while Chapters IV and V deal respectively with differential equations, forced vibrations, null effects (dynamic damping), and the most recent developments of the notions " complex conductance " and " complex resistance."

The second part of the work is devoted to technical and practical aspects, especially to methods for calculating critical speeds. These matters will be found to be of particular interest by those who have to carry out such design calculations frequently or as a routine. Vibration of vehicles, including ships, having already been dealt with in the first part, the author concentrates here on torsional and transverse vibrations.

With the intention of keeping mathematical requirements to a minimum, certain otherwise convenient techniques are not employed such as the Laplace transformation, and the matrix notation for differential equations. Matrices are only used in the final chapter in the form of transfer matrices, for without them it seems impossible to deal with transverse vibrations in cases which are of practical importance. Another enforced omission, if the framework of the book was not to be exceeded, is that of problems leading to non-linear differential equations, or to linear equations with variable coefficients.

Books Received

Mechanical World Year Book, 1961. Emmott and Co., Ltd., 31, King Street, West, Manchester, 3. Price 5s.

Mechanical Design of Hydro Plants. Vol. 3. Tennessee Valley Authority, Knoxville, Tennessee. Price 3.75 dollars.

Mechanical World Electrical Year Book, 1961. Emmott and Co., Ltd., 31, King Street West, Manchester, 3. Price 4s.

Who's Who in the Motor Industry. 1961 Edition. The Temple Press, Ltd., Bowling Green Lane, London, E.C.1. Price 42s.

Nuclear Reactor Containment Buildings and Pressure Vessels. Butterworths, 4 and 5, Bell Yard, London, W.C.2. Price 100s.

Tropical Houses. By David Oakley. B. T. Batsford, Ltd., 4, Fitzhardinge Street, Portman Square, London, W.1. Price 42s.

Pacific Steam : The British Pacific Locomotive. Percival Marshall and Co., Ltd., 19-20, Noel Street, London, W.1. Price 12s. 6d.

Engineering Drawing. Book Two. By F. E. Page. Chatto and Windus, Ltd., 40-42, William IV Street, London, W.C.2. Price 12s. 6d.

Understanding Organizational Behaviour. By Chris Argyris. Tavistock Publications, 11, New Fetter Lane, London, E.C.4. Price 38s.

Algebraic Equations. By Edgar Dehn. Dover Publications, Inc., 180, Varick Street, New York, 14, New York. Price 1.45 dollars.

The Theory of Equations. Vol. 1 and 2. By William Burnside and Arthur William Panton. Dover Publications, Inc., 180, Varick Street, New York, 14, New York. Price 1.85 dollars. each.

Strength and Elasticity of Materials and Theory of Structures. Vol. II, Second edition. By W. H. Brooks. Macdonald and Co. (Publishers), Ltd., 16, Maddox Street, London, W.1. Price 30s.

Studies in Business Organisation : A Supplement to " Business Enterprise." Edited by Ronald S. Edwards and Harry Townsend. Messrs. Macmillan and Co., Ltd., St. Martin's Street, London, W.C.2. Price 25s.

An Elementary Treatise on Curve Tracing. By Percival Frost. Revised by R. J. T. Bell. Chelsea Publishing Company, New York, N.Y., 50, East Fordham Road, New York 68, N.Y. Price 3.50 dollars.

Transcendental and Algebraic Numbers. By A. O. Gelfond translated from the first Russian Edition by Leo. F. Boron. Dover Publications, Inc., 180, Varick Street, New York, 14, New York. Price 1.75 dollars.

Obituary

JOHN E. CALVERLEY, M.I.E.E., M.I.Loco.E.

MR. JOHN E. CALVERLEY, who died recently at the age of seventy-five, will be remembered by electrical engineers, primarily as an orginator. In his advocacy of high-voltage d.c. transmission of electricity he was ahead of contemporary thought and practice, at a time when the British 132kV Grid was setting the pattern of progress. To-day the cross-Channel cable link is approaching completion and other d.c. transmission projects are being developed, and Mr. Calverley's faith in the system, over the last forty years, is proving to be well founded.

John Calverley was born in Bentham, Yorkshire, in 1886, and educated at Bentham Grammar School and Bradford Technical College. He began his career in electrical engineering as an apprentice earning five shillings a week. In 1908 he joined the Phoenix Dynamo Company, Bradford, (which later became one of the founder firms of the English Electric Company) as an assistant draughtsman. Two years later he went to Dick Kerr and Co., Preston (another constituent member of English Electric) as an assistant design engineer. There he did a great deal of pioneering work in the design of d.c. machines and gained an international reputation on the design of high-voltage d.c. machines. His interest in high-voltage d.c. transmission originated in the early 1920s when he was a co-inventor with the late W. E. Highfield of the transverter which was demonstrated at the Empire Exhibition at Wembley in 1924. For a time he was associated with the late Monsieur Thury in developing machines for the Thury high-voltage d.c., constant-current system, the principles of which were well exemplified in the Moutiers-Lyons network.

From 1920 to 1930 Mr. Calverley was chief designer, d.c. machinery, at the English Electric Company's Preston works. In 1930 he became chief d.c. engineer and in 1935 chief engineer and manager of the company's traction department. Amongst other things he developed high-voltage d.c. machines for the regional transmitting stations of the B.B.C. During the war he was sent to Washington in 1941 to represent the Ministry of Supply as adviser on d.c. electrical equipment for tanks and army vehicles. On returning to Great Britain in 1943 he was appointed deputy chief engineer (technical) to the English Electric Company, Ltd. From 1952 until his retirement in 1955 he was a special consultant to the company.

He served on several technical committees with the Institution of Electrical Engineers, the Electrical Research Association, the International Electrotechnical Commission, the British Standards Institution, and the Conference Internationale des Grands Réseaux Electriques on which he was, for many years, chairman of the group that studied high-voltage d.c. transmission.

Oil Tanker Terminal at Angle Bay

The limitation of the size of oil tanker able to use the port of Swansea coupled with the increasing deadweight of these ships, caused the British Petroleum Company, Ltd., to search for a place where there was deep water and adequate manoeuvring space for large oil tankers. Angle Bay on Milford Haven was selected as fulfilling the requirements and a berthing jetty has been built together with a tank farm and a pipeline to convey crude oil to Llandarcy refinery. Popton Fort has been adapted for administration purposes and bunker fuel oil supply tanks constructed within the lower battery.

CONTINUED expansion, since the war, of the consumption of oil products for a wide variety of industrial and domestic applications, coupled with the development of the oil refining industry, has called for large tanker fleets for the transport of crude oil from the sources of supply. The economics of the transport of oil by sea have resulted in a steady increase in the size of oil tankers, until to-day ships of 100,000 tons deadweight are being built. Vessels of such size call for special berthing facilities and an adequate depth of water at all states of the tide. Since the approaches to Swansea limit the size of tankers which can enter the port, British Petroleum Company, Ltd., even as early as 1948 when tankers larger than the utility size of 18,000 tons were beginning to enter service, began to search for a place, not too distant from its Llandarcy refinery at Swansea, where adequate depth of water was available to accommodate vessels of 40ft draught and over. Such a place was found at Angle Bay on the south shore of Milford Haven where there is sheltered water of adequate depth and sufficient area to provide space for the manoeuvring of larger ships. The site selected for the terminal is distant some 60 miles from Llandarcy Refinery so that besides building a marine terminal, tank farm and ancillary installations, it was necessary to construct a pipe line to connect the terminal with the refinery.

Following the acceptance of the plan by the local authorities and the National Park Commission and the granting of the necessary way leaves, and the approval of the scheme with the passing of a private Government Bill, the company bought Popton Point, which includes Popton Fort built in 1863, a coastal strip amounting to some 140 acres extending along the shore of Angle Bay from Popton Fort to Kilpaison farm, and Kilpaison farm of 220 acres.

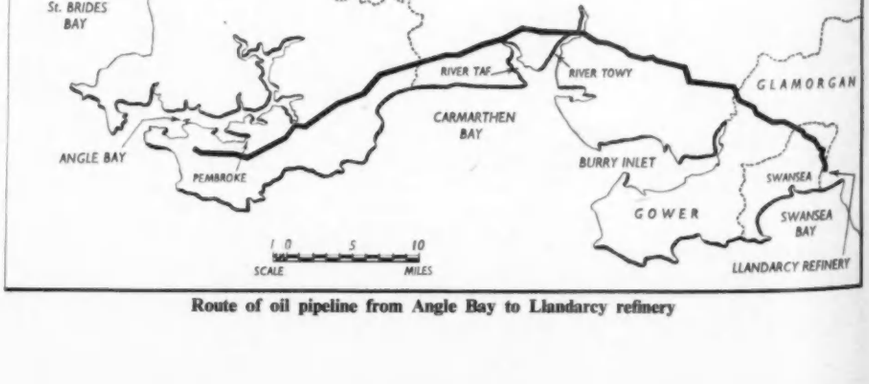
Work on the project began in 1957. The building of the jetty and tank farm and the reconstruction of Popton Fort together with the laying of the pipeline were completed in 1960, and the ocean terminal became operational in August of that year with the berthing of the company's oil tanker "British Statesman" of 42,000 tons deadweight. The official opening of the terminal was performed on April 20 by the Right Honourable Richard Wood, Minister of Power, when he unveiled a plaque. The Minister commented that oil tankers had grown enormously in size since the 224-ton brig, "Elizabeth Watts" brought the first cargo of oil from the U.S.A. 100 years ago. He also referred, in his remarks, to the new tax on heavy oils and refuted the idea that it was intended to protect coal. The tax, he continued, would not check the expansion of the consumption of oil which had an essential role, in our economy, in supplying energy to our growing industries and so supporting our standard of living. The Honourable M. R. Bridgeman, the chairman of The British Petroleum Company, Ltd., thanked all the various bodies which had made this project possible, and commented that if the Suez Canal is deepened the company may consider building tankers of 80,000 tons. However, present planning of tonnage related to the 50,000 ton deadweight tankers currently in service and tankers of 67,000 tons now under construction. The chairman added that developments in Wales would call for increased supplies of oil when the new petroleum chemical works, the construction of which has now commenced at Baglam Bay, near Llandarcy, came into operation towards the end of 1962.

Aerial view of Ocean Terminal showing jetty, approach road, Popton Fort and bunker fuel tanks

Ocean Terminal

The general arrangement of the terminal can be seen in our illustration which shows the jetty with its two berthing heads and Popton Fort. For the accommodation of oil tankers there is a jetty which has been sited in the lee of Popton Point to provide shelter from the prevailing westerly winds. The main section of the jetty is 1220ft in length and incorporates two berthing heads each capable of taking a 100,000 tons deadweight tanker and each extending to the edge of the deep water channel where there is about 55ft of water at low tide. The berthing heads each consist of two dolphins with a six boom hose handling gantry carried on a piled platform linking the dolphins. Each dolphin, known as a gravity structure, consists of a lozenge shaped strong point of solid mass concrete measuring 74ft by 38ft contained in an enclosure of sheet steel piling driven down to the rock. The structure has been designed to withstand the berthing forces, imposed by tankers, through the medium of gravity fenders. At each dolphin there are four rectangular weights, each containing 100 tons of concrete and each supported by pairs of links. This arrangement provides for the weights to have a horizontal movement of 4ft 10½in and a vertical movement of 3ft 6in. One set of four weights will absorb the energy of a 65,000 ton tanker approaching at about 0·5 knots.

The trunkway of this jetty is carried on two lines of hexagonal piles and at each end there are mooring dolphins which give the jetty an overall length of 2300ft. Connecting the jetty to the shore is an approach 1350ft in length which carries a 16ft wide roadway and a pipe track 32ft wide. The latter carries,



Route of oil pipeline from Angle Bay to Llandarcy refinery

in addition to twin 26in diameter crude oil pipe lines, three 16in diameter bunker fuel lines, two 12in diameter lines, (one for diesel fuel and one water for fire fighting) and one 10in diameter potable water line. To offer the least resistance and interference to tidal flow and to provide a passage for small boats open construction has been employed and the pre-cast, post-tensioned concrete superstructure, using 1¼in Macalloy bolts each tightened to 35 tons, is supported on three rows of hexagonal piles driven into rock and capped with pre-cast concrete muffs. The pile bents are at 27ft 6in centres and Raker piles at every fifth bent take care of sway while the road slab spreads the wind load between the anchor bents.

Popton Fort, which was last fully garrisoned in 1904, has been repaired and adapted as an administration and service area. Accommodation has been provided for marine staffs, &c. and there is a stores section, fire and first aid stations, while a V.H.F. radio telephone system provides for communication with tankers approaching the terminal up to a distance of 30 miles out to sea. There is also a single link teleprinter service to Llandarcy refinery. In the lower works of the fort have been built : two marine fuel tanks each of 11,000 tons capacity and measuring 120ft diameter by 36ft in height ; two tanks of 7000 tons capacity, one for heavy fuel and one for diesel fuel, each being of 90ft diameter by 36ft ; and one potable water tank holding 250,000 gallons. The water is supplied from the Pembroke Rural District Council waterworks at Stembridge, while the oil is shipped from Llandarcy by small tankers. The oil tanks are sited in an oil tight rock excavation and drainage passes through separators before entering the Haven. For handling the bunker oil there are three Mirrlees 250 tons per hour screw displacement pumps, each powered by an electric motor rated at 175 h.p. at 975 r.p.m., mounted within an old battery casemate. From storage tanker to pumps the pipe lines are steam traced using steam at 50 lb per square inch, and from pump to jetty heating is by " Pyrotenax " coaxial cable, the average temperature, which is controllable, being 70 deg. Fah.

Tank Farm and Pipeline

About 65 acres of the 220 acres acquired at Kilpaison have been utilised for the installation of eight 114ft diameter by 60ft high tanks, each of 21,000 tons capacity. These floating roof tanks of all welded construction are grouped in pairs, each pair being contained in a bund. The tank farm, which is at the south-east corner of Angle Bay and about 1½ miles from the jetty, is supplied with crude oil which is delivered by the ships' pumps through two 26in diameter buried transfer pipelines. These pipelines connect with a manifold near the tank farm pumphouse, from which further 26in diameter lines connect with each pair of tanks, and this pipe linkup provides for any pair of tanks to be emptied or filled or the contents to be transferred to one or both of any other pair of tanks. The main pumping installation is sited at 17·5ft above O.D. and consists of four Hayward Tyler 700 tons per hour centrifugal pumps, each powered by a Bruce Peebles 650 h.p. motor operating on 3·3kV. The pumps work in parallel with a differential between pumps of approximately 200 lb per square inch, giving the pipeline, linking the tank farm and the refinery, a working pressure of about 850 lb per square inch. This 18in diameter pipeline rises to an elevation of 672ft and the pumping capacity of the system has been designed, not only to avoid the need for booster stations, but to ensure constant flow and so avoid any possibility of hydraulic shock due to gravity flow after the highest point in the line has been passed. A minimum of two pumps is on load at any one time while it is considered that with the present output not more than three pumps will be required to supply Llandarcy.

The route of the 18in diameter pipeline connecting Angle Bay with the Llandarcy refinery is shown in the accompanying sketch map and runs mainly through open country in Pembrokeshire, Carmarthenshire, Glamorgan and Swansea County Borough, where it is buried at a minimum depth of 2ft 6in. Many man-made obstacles had to be surmounted : these included over 100 roads, twelve railway crossings, four major rivers, a canal, twenty-eight streams, three underground aqueducts and a number of main gas lines. The South Durham Steel and Iron Company, Ltd., supplied the 62 miles of pipe, which was laid by George Wimpey and Co., Ltd. To lay the pipe a working strip, 40ft wide, was cleared of all obstruction and the top soil removed ready for replacing after the completion of the pipe laying. The 25ft lengths of steel pipe wrapped in glass fibre and with an external coating of bituminous enamel were laid along the route and butt welded together. After radiographic examination, the welds were given the same protective coating as the pipe and this coating was tested for homogeneous seal by a high-voltage " holiday detector " machine. All joints were tested under an air pressure of 100 lb per square inch and all bends needed during laying were done on the spot by an hydraulic cold bending machine, the minimum radius of any bend being 18ft to permit the use of go-devils. Although external corrosion of the pipe is not expected to attain any significance for a long time, preparations have been made to provide cathodic protection when conditions warrant it. Upon completion of the pipeline it was cleaned by passing a go-devil through it and progress was recorded by a number of listening posts arranged along the route. The cleaning operation was completed without incident.

The consulting engineers for this project were Rendel, Palmer and Tritton, and the work was carried out by—Christiani and Nielsen, Ltd., marine civil engineering ; Constructors John Brown, Ltd., mechanical and electrical work ; Weldall and Assembly, Ltd., gravity fenders ; Motherwell Bridge and Engineering Company, Ltd., tank construction ; George Wimpey and Co., Ltd., main pipeline ; Lincoln Electric Company, Ltd., welding equipment.

Royal Institution of Naval Architects

ANNUAL SPRING MEETING

No. IV—(*Continued from page 657, April 21, 1961*)

PROFESSOR E. V. TELFER was in the chair when the meeting was continued on Wednesday afternoon with the reading of :

SCALE EFFECT EXPERIMENTS ON VICTORY SHIPS AND MODELS
(Parts III and IV)

By A. J. W. Lap and J. D. van Manen

Synopsis

In Part III results are presented of open-water tests with geometrically similar models of a Victory wake-adapted screw to six different scales, ranging from scale 50 to scale 6. An analysis of these results was made according to Lerbs' method of the equivalent radius of the screw. This analysis enabled conclusions to be drawn about the effect of Reynolds number on the open-water test results of this type of screw.

In Part IV the results of self-propulsion tests with Victory models to scale 6, 18, 23, 30, 40, and 50 at self-propulsion point of model are analysed on the basis of the results of open water propeller tests. The analysis is made both according to the methods of thrust identity and torque identity. Tabulated values are given for all the propulsive components at speeds corresponding to 10–17 knots for the ship. Mean values of these components are represented in diagrams on basis of model scale. A method is introduced for plotting thrust-deduction as a function of thrust.

Mr. H. Lackenby, M.Sc. : The two previous papers in the series showed appreciable scale effect on the hull factors W, t and hull efficiency which gave rise to much discussion and speculation. The scale effect was quite appreciable, amounting to about 15 per cent over the range of tank models tested and somewhat more if one included the model boat. As regards the overall effect, however, the missing link was the propeller efficiency, and we now have that.

We find that the variation in the propeller efficiency through the model range goes the other way and has a steadying effect on the Q.P.C. (or total propulsive efficiency, as the authors call it). This is plotted and the diagram still shows a variation in Q.P.C. with scale, but a much reduced one as compared with the propeller and hull efficiencies.

If you try to extrapolate to the full scale, using the tank results alone, you get an answer quite different from that which you would get if you included the single model boat result. This peculiar effect also applies to several other diagrams in the paper.

Although the authors have presented their results at model self propulsion point, from the practical point of view it is also of interest to consider the scale effect at constant screw loading. The authors have done this partly, but have not carried it through to find its effect on the Q.P.C. We have tried this at the B.S.R.A. by correcting the thrust deduction to a constant loading, using the information given in the paper. We found (*a*) the variation in t at constant loading is not so great as at S.P. point ; and (*b*) the effect on Q.P.C. is to level out still further the values over the range of the five tank models. There is still, however, a pronounced dive down to the model boat spot. Neglecting the model boat, therefore, and taking the trend from the tank results only, one would say there was hardly any scale effect on Q.P.C. at constant loading.

I feel that the fact that the scale effect on hull efficiency largely cancels out the scale effect on propeller efficiency is rather fortuitous. Clearly, further work like this on other types of ship is required to throw more light on the matter.

Mr. R. N. Newton, R.C.N.C. : It is stated that the effective wake factors are independent of speed and, later, that the thrust deduction is dependent partly on the velocity distribution behind the ship form. Whilst it may be true that effective wake is independent of speed so long as the ship is not generating large waves, this is not necessarily so at higher speeds. Indeed, as I indicated to the

ninth I.T.T.C., there is an oscillatory variation in the values of the wake factor and thrust deduction factor for fast slender forms. Investigations at the Admiralty Experiment Works have shown clearly that for twin screw ships the wake factor varies with Froude number according to whether a trough or crest of a wave occurs at the propeller position. The wake factor reaches peak values when there is a crest at the propeller position and minimum values when there is a trough at this position.

Similarly, the thrust deduction factor reaches peak values when there is a trough at the propeller position and minimum values when there is a crest at that position, and the magnitude of the variation is quite appreciable. Consequently an appreciable error would be involved if the hull efficiency is based upon the mean values of the wake and thrust deduction factors, and this error might well compare with any scale effect.

As a result of this experience, it is now the practice to carry out model propulsion experiments for a series of as many as 20 or 30 Froude numbers to define the curves of the hull efficiency elements.

Therefore, had the model experiment series described in the paper been extended over a wider range of speed, the authors would have found a family of curves, dependent upon Froude number instead of the singular curves which are shown.

Dr. F. H. Todd, B.Sc., Ph.D. : In Parts III and IV, now presented, we are given considerably more information about the various components of the propulsive efficiency. The thrust deductions are exactly the same as those given in Part I. The original wake fractions given in Part II were for nominal wakes measured by pitot tubes. In the present paper we are also given the effective wakes measured by the propeller behind the model ; they are everywhere smaller than the nominal wakes. The difference is smallest for the smallest model and is greatest for the one-sixth scale model. If we use the effective wakes to calculate hull efficiency we find that the values are slightly different from those in Parts I and II, derived by using the nominal wake. But the general picture of a hull efficiency decreasing quite rapidly with increase in size of model remains. The variation in hull efficiency is also given. There is also additional information in this paper on open efficiencies for the different propellers ; the open efficiency increases very materially in going from a one-fiftieth scale model to the one-sixth scale model, from about 0·5 to 0·65. Since the relative rotative efficiency remains practically unaltered, the increase in open efficiency with size of model goes a long way towards counteracting the reduction in hull efficiency, and as a result the quasi propulsive coefficient remains almost constant over the scale range.

All these results have been derived for model self-propulsion point and therefore, in going from the smallest to the largest model, we are dealing with successively lighter loaded propellers. The K_T value actually decreases from 0·27 to 0·224 from the smallest to the largest model. It has been suggested that if the analysis were made for each model at a simulated ship self-propulsion point, the result of the analysis might be quite different. The authors have investigated this by running overload tests with the one-sixth scale model and they state that the effect of changes in propeller loading on w is negligible and that on t it is small, so that as a result the total effect of propeller loading on the hull efficiency h is small in comparison with the scale effect on the propeller. Assuming that the wake fraction and thrust deduction fraction, and therefore also the hull efficiency, will not be materially affected by changes in model loading, and taking the open efficiency for the propeller as being appropriate to that for the K_T value of the one-sixth scale model, namely 0·224, a new open efficiency curve can be obtained, and this, in association with the hull efficiency and relative rotative efficiency, leads to a new Q.P.C. curve.

Looking at this Q.P.C. curve, the propulsive coefficient drops from 0·8 for the smallest model to 0·675 for the largest. More important even than this is the fact that the Q.P.C. for the models of scales one-twenty-third and one-eighteenth, which would be about the largest normally used in experiment work, is about 0·78, and therefore the drop to the one-sixth scale is some 13 per cent. I would hesitate to predict the propulsive coefficient for the ship from the data shown in these curves, and cannot see how the authors can state that " the results given in this paper give rise to some optimism with respect to the realisation of a prediction method for the power/r.p.m./speed relation for the full scale ship." Whilst it could be argued that the change in propulsive efficiency throughout the range of scales tested does not vary very much, this is only due to the fact that in this particular case very large changes in open efficiency and in hull efficiency happen to practically cancel one another out. We have no grounds for assuming that this would happen in another particular form of ship. One can understand the increase in open efficiency as we go to bigger and bigger models, and one of the most mystifying features of the curves is the sudden rise in t and the corresponding very steep fall in h when going from the one-eighteenth scale model to the one-sixth scale model. The latter is really a small ship, some 72ft long, and it was not run in an experiment tank, but in the open sea. One is therefore rather tempted to ask whether the authors are satisfied with the results derived from this particular size of model.

It is not possible to do a complete analysis of the effect of propeller loading on the various components of the propulsive efficiency without the necessary model data for each of the different size models. The paper gives tables showing the variation of thrust, torque, &c., for each scale model at a number of speeds, but only for the model self-propulsion point. If the authors have also run those models at each speed over a series of different loadings, I think the profession would be indebted to them if they would make the information available so that we can each make our own analysis into this disturbing situation. The present paper confirms the previous data on the scale effect on hull efficiency and thrust deduction and offers no further explanation of their behaviour. Perhaps a detailed analysis of overload tests would help to clear up the question of whether or not the explanation lies in this direction.

Dr. G. Hughes, D.Sc., Ph.D. : In an appendix of a paper I read before the Institution in 1957 I made a complete re-analysis of the " Victory " models, and the model boat " D. c. Endert, Jr." I concluded that there was considerable doubt about the results obtained on the " D. C. Endert, Jr." trials on wake and the measurement of speed, and there seemed to be throughout the trials some indication of increase of roughness. In the discussion in the paper I thought the authors of the present paper rather tended to dispute my conclusions, and I would ask if, in the light of what has been said here to-day, inasmuch as the " D. C. Endert, Jr." results seem to be out of line in some respects, they would reconsider what I said on that earlier occasion.

The Chairman : There is complete unanimity that the model boat is a small ship and the models are of wax. Mr. Lap has used the idea of a specific thrust and a specific resistance, but his specific values are referred to the inflow speed of the propeller. I suggest that if we use a specific resistance due to ship speed, and if we have a thrust based on ship speed, when we plot thrust against resistance we get a single line for all the models. For the boat, rough or smooth, we get the same line, and for the model, rough or smooth, you get the same point of extrapolation.

So that there is something in common between the boat and the models, and that indicates that possibly there is a speed or a resistance error in the boat itself.

Professor W. P. A. van Lammeren : The main conclusion seems to be that more information should be made available before the results can be generalised. The scale effect concerns only one series of models. Maybe, however, before long there will be another opportunity to obtain further results. Last year there was put into operation a plain ship, about 190ft long and having a displacement of 400 tons or thereabouts. It may be possible to arrange to carry out experimental measurements of thrust and speed, and manoeuvring tests ; maybe even the resistance of the ship could be measured.

If you all think that such tests would be of interest to the profession we shall do our best to carry out full scale trials with the ship.

The second paper presented on Wednesday afternoon, March 29, Professor E. V. Telfer presiding, was :

THE EFFECT OF FOREBODY SECTION SHAPE ON SHIP BEHAVIOUR IN WAVES

By W. A. Swaan and G. Vossers

Synopsis

Experiments have been carried out with a series of six models. These models had the same principal dimensions and displacement, but differed in section shape in the forebody and in prismatic coefficient. Results are presented from tests in head seas and in bow seas. Measurements have been made of pitch, heave, motion of the bow relative to the waves, thrust increase, and midship wave bending moments.

It is concluded that " U "-shaped sections are advantageous as regards wetness, speed loss, bending moments and even as regards slamming on some occasions. " V "-shaped sections are advantageous as regards motions, especially in waves longer than the ship (i.e. for small ships).

Furthermore, it is found from the experiments that decreasing the midship coefficient is unfavourable in regard to wetness and the tendency to slamming. To reduce speed loss a low midship area coefficient is to be preferred for fast vessels and a large value for slower ships.

Experiments with a model having extreme flare above water in the forebody showed only a small influence on the motions. The extreme flare, however, made the model much more susceptible to slamming.

Discussion

Dr. H. Edstrand : As a critic I am in the happy situation of having results of an investigation very similar to that presented in this paper ; it was carried out at the Statens Skeppsprovningsanstalt. I agree that the average propulsive performance of a model in regular waves very much resembles that in still water. We established the difference between wave and still water performance from wave and overloaded still water propulsion tests and have plotted the results on a graph, where the ordinate shows the alteration in propeller efficiency in the

behind condition when going from still water to regular waves. In spite of the very severe motions, values less than 0·75 were not recorded. Comparing the results with those of the authors, the maximum efficiency drops are of similar magnitude in both investigations.

The authors did not introduce a frictional correcting force because they feared a disturbance of model motions. We used a correcting force on a long length (about the model length) of fine wire, and when checking the model motions with wire, self-propelled, against the motions in the internally towed condition without wire no significant departure was observed.

The pronounced difference in the heave behaviour of the models in long waves was duplicated in our tests. The less evident pitch difference also occurred. I agree in general with the authors' conclusion on the superiority of " V "-shaped forebodies from the point of view of motions.

Our investigations were not at all so conclusive as to the preference for " U "-shaped sections with regard to speed loss. Also from the authors' figures for non-dimensional thrust increase for six models at full draught the " U " bow form seems to be the best only at the lower Froude number 0·15. For Froude numbers 0·20 and 0·25 the α=170 deg. direction favours the " UUV " bow and α=130 deg. the " UVV " bow. Our investigations showed dominant " V " form superiority for waves with $\lambda/L \geq 1 \cdot 25$, but no clear trend for shorter waves.

The authors' preference for " U "-shaped sections with regard to slamming is unconventional. Slamming by impact to portions of the bottom of the model might never have occurred in the test, but it is the form of slamming which most frequently causes damage in service. The type of slamming occurring in the authors' tests against an extreme and, for merchant ships, unrealistic flare should not lead us to depart from the prevailing opinion that " U " forms are more liable to slam in waves, which is also demonstrated in practice.

Mr. R. N. Newton, R.C.N.C. : Much remains to be done before the most significant parameters of motion, wetness, resistance and bending moment in waves can be segregated. In the section on the effect of section shape in the forebody the authors say that the diagrams comparing the " V " and " U " bow for thrust, pitch and heave show that in general the wavelengths for which one of the models has an advantage are the same for both high and low speed. I suggest that whilst this is more or less a true interpretation of the results so far as pitch and heave are concerned, it is not true as regards thrust increase. The plottings show that while the " U " bow is superior at F_n 0·15 at all wavelengths, it loses this superiority in waves of 1¼ ship lengths or longer at F_n 0·25. This is as expected, and at even higher F_n's one would expect the " V " bow to have the advantage, not only as regards thrust, but also as regards pitch and heave.

Whilst it is true that the " V " bows are finer than the " U " bows under water, they provide the ship with much greater reserve of buoyancy and one ponders on the magnitude of the individual effects of the change in form below water and above water. Similar methodical series experiments on slender warship forms carried out at A.E.W. have been compared with those given by the authors for Froude number 0·25, and have shown conclusively that the major contribution to effect on motion or thrust is made by a change in the above water form.

As regards the effect of flare on thrust, or resistance, the comparison between the fine and full form is very different. The authors show that for the full form heavy flare at the bow above water leads to an appreciable increase in thrust. With the slender warship form we have the same figures for pitch and heave as the authors have obtained, but not as regards thrust ; a substantial increase in flare, or in freeboard, resulted in a reduction in resistance of up to 20 per cent.

All this points a moral that little is to be gained as regards motion and dryness by changing the under water form within the practical limits imposed by other design requirements.

The important requirement for dryness is adequate freeboard ; therefore, I was disappointed, that the authors' experiments did not include freeboard as a main parameter and that observations of wetness had not been made.

The authors give the results of the effect of variation in the forebody waterplane coefficient on pitch and heave for a Froude number 0·2 at different wavelengths. At the A.E.W. that was done by changing the buoyancy. The experiments there were aimed at determining the effect of changing the LCB position from 7½ per cent aft of amidships to 1¼ per cent forward of amidships. The consequential change in C_{WP} was from 0·5 to 0·68. Although the results were not directly comparable, the trend was found to be the same, i.e., the pitch was found to increase as C_{WP} decreased for λ/L=1·2, but the effect on heave was very much reduced.

These comparisons point to the need for more methodical work on different basic forms, since it is clear that the effect of variation of any one parameter on a slender form is not necessarily repeated on a full form. I suggest that freeboard forward should be made a main parameter of any such series, and there appears to be a need to define flare so that the effects of its variation can be studied systematically.

Dr. F. H. Todd, B.Sc., Ph.D. : May I repeat what I said at the New York meeting last year, that I should like to see included in the research variations of the position of LCB, for I feel that the good smooth water results obtained in rather full ships by having the LCB in a forward position might not be a true measure of the behaviour of these ships in average sea-going conditions, The latter might be better achieved by having a finer entrance with the LCB somewhat further aft.

The general conclusions one draws from the results are that " U " sections in the forebody are in general to be preferred to " V " sections. " U " sections delay slamming and wetness of decks, they show the least power increase in waves and therefore also the least speed loss, and moreover there are lower vertical bending moments in the hull by as much as 30 per cent. The only real merit of the " V " type bow sections appears to be a reduction in the pitch and heave motions in waves longer than the length of the ship. Considering general sea-going conditions, this means that " V " sections may be preferable on small ships, but for large and particularly the high speed ships a " U "-type forebody is likely to be the better choice.

Slamming has usually been associated with the forefoot emerging from the water and going back at a relatively high velocity, causing vibration and possibly damage to the bottom of the ship over the first 20 per cent of the length. Similar effects, however, have been observed in aircraft carriers when pitching in such a way that the very large flare associated with the wide flight deck came into the water.

Mr. G. J. Goodrich, B.Sc. : The effect of forebody shape upon the behaviour of ships in waves is a very important aspect of hull design. The results for the increase of thrust, however, could have been enhanced by the addition of the thrust curves for calm water ; the thrust plotted in the paper are all taken as the addition above the calm water thrusts. It is therefore not possible to determine loss in speed curves for each of the models.

The influence of wavelength on the measured vertical midship bending moment and the comparison of the experimental results with theory is interesting ; it would be of further interest if the static moment calculated by the standard method could be specified in the diagrams. The fact that the experimental values are less than the calculated values is almost certainly due to the overestimation of the wave height in the theoretical calculations. The presence of the ship causes an attenuation in the wave height, particularly in the after body, as the ship pauses on the wave ; the attenuation can be as high as 50 per cent.

Mr. M. N. Parker, B.Eng. : In their introduction the authors suggest that the main conclusion from Mr. Kent's work on the influence of bow form on sea-going behaviour was to show that one has to make major alterations in section shape to find significant changes in ship behaviour, and that appears to be borne out by the results given in this paper. Here we have marked changes in section shape, and it is surprising that the differences in behaviour have not been greater than those recorded. Perhaps if the experiments had been carried into the non-linear range we might have seen bigger differences.

It is clear that there is no simple answer as to whether " U " or " V "-shaped sections are the better from the seakeeping point of view. The " V "-shaped sections generally seem to be the best so far as the absolute motions are concerned, but from the point of view of relative bow motion and the thrust required, the " U "-shaped sections seem to be better, and the choice will clearly depend on the significance attached to each of these in any particular service and also on whether the sea conditions the vessel is likely to meet will give rise to a severe motion or not.

On reading the paper I was disappointed to see that the only indication of the effect on power was the thrust increase. I note, however, the authors suggest that the propulsive efficiency for the particular loading, and hence the drawbar horsepower, may be calculated with sufficient accuracy from still water data. Seakeeping experiments are usually carried out with relatively small models and at model self-propulsion point. This means that a propeller designed for ship self-propulsion point is very heavily overloaded and is thus operating on the linear part of the efficiency curve, and it may be questioned whether the effect of variations in inflow velocities might have a greater effect on the mean propulsive efficiency on the ship, where the propeller will not be overloaded to the same extent, even in a seaway.

Professor J. F. C. Conn, D.Sc., was in the chair when the spring meeting was con-

tinued on Thursday morning, March 30, with the presentation of :

THE STABILITY AND CONTROL OF DEEPLY SUBMERGED SUBMARINES

By T. R. F. Nonweiler, B.Sc., Ph.D.

Synopsis

This paper presents some notes on the deductions from a mathematical study of the motion of a submarine in the vertical plane, ignoring effects of the free-surface. Mathematical analysis is omitted, but a criticism is offered of the fundamental assumptions of the analysis, and a distinction drawn between such essential assumptions, and those introduced to simplify the treatment. Some comments on the results of the simplified analysis of submarine stability and response to specific disturbances leads to a discussion on the method of ship control, particularly having in mind the wide range of operating speeds now possible. Finally some differences revealed in the unsimplified treatment are pointed out.

Discussion

Mr. R. N. Newton, R.C.N.C. : This simple treatment of so complex a subject, using ordinary diagrammatic drawings, at once makes clear the wide difference between slow and high speed submarines in the nature of the stability and the factors affecting control. The drawings illustrating high speed and low speed free motion indicate clearly the different attitude adopted by the submarine under the action of an impulse through the C.G. (e.g., by hydroplane angles deflected in the same sense on the forward and after hydroplanes), or under the action of a wrench (e.g., by applying hydroplane angles in the opposite sense).

The drawing illustrating trim and manoeuvre points and the appropriate notes bring out the significance of the siting of the hydroplanes along the length of the submarine. For instance, at quite low speed it is possible for the trim point (sometimes called the critical point) to be abaft the after hydroplanes. In this case the effect of applying after plane angle is the reverse of what normally happens. In the submarine world this is known, I believe, as the " Chinese Effect." For operational reasons it may be desirable to make the critical speed, i.e., the speed at which the trim point coincides with the after planes, as low as possible.

By similar reasoning care is also necessary in the siting of the forward hydroplanes. For a given maximum speed there is a corresponding position of the trim point, and if the planes are fitted forward of this point a nose-up angle will cause a bow-up moment and cause the ship to rise. The response will be the reverse if the forward planes are fitted abaft the trim point. By and large it would appear advisable to place them at or before the neutral point, to avoid any change in technique on the part of the operators or control system at the critical speed.

Another important fact emerging from the paper is the effect of the position of a third point—the manoeuvre point, which also moves towards the neutral point as speed increases—on the curvature of the path, and therefore on the depth required to pull out from a steep dive or rise.

It is obvious from the paper that the problems of the designer are far more complex for a high speed than for a slow speed submarine. He is faced with two major tasks. The first is to be able to predict accurately the value of the high speed stability criterion X and the second is to assign to it a value which will effect the best compromise between stability and control.

Such problems are receiving the closest attention at the Admiralty Experimental Works, where a new facility, the rotating arm, has been installed to carry out dynamic stability tests on models and so to determine the various coefficients. To provide the coefficients for the complex theory involving non-linear coefficients and derivatives arising from cross coupling effects, the data obtained from rotating arm experiments is essential. In step with such model experiments, full scale trials are being conducted, aimed at assessing scale effects, and one of the difficulties in achieving model-ship correlation is that of carrying out ship manoeuvres from which useful data can be obtained, in a restricted depth of water.

The other facility recently installed at the A.E.W., which is equally essential to the solution of the whole problem of stability and control of submarines, particularly as regards the non-linear theory, and the effect of derivatives arising from cross coupling effects, is an analogue computer. This computer has already been used with equations of motion representing five degrees of freedom, and we are in process of setting it up for six degrees of freedom.

Mr. L. J. Rydill, R.C.N.C. : I consider that Dr. Nonweiler has made a greater contribution to submarine stability theory than has any other investigator in this field. and he is the pioneer of the concepts, the neutral and trim points. I am not familiar with the concept of the manoeuvre point and not so convinced of its usefulness, but consider that understanding of the significance of these concepts would be improved by pointing out that the neutral point is simply the centre of pressure, and that the trim point is the effective centre of pressure. The importance of the trim point lies in its position relative to the positions of the forward and after hydroplanes : the force applied by hydroplanes is most effective when it is furthest from the trim point. At low speeds the trim point is well aft and the forward hydroplanes are most effective ; in fact, this is why forward hydroplanes are needed in submarines—for control at low speeds, when the after hydroplanes are relatively ineffective. At moderate to high speeds the trim point is close to the neutral point, which is usually of the order of 25 per cent. of the length from the bow, and the after hydroplanes are more effective. Two interesting points arise from this.

First, recent U.S. Navy practice in siting the forward hydroplanes on the bridge fin, i.e., further aft than formerly, is open to criticism on the grounds that it reduces their effectiveness at both low and high speeds, because of their reduced lever about the trim point. Secondly, the concept of the neutral point is also applicable to motion in the horizontal plane, and herein lies the explanation of the well known relative ineffectiveness of a forward rudder—its lever about the neutral point is much smaller than that of an after rudder.

In regard to the author's novel suggestion that the after hydroplanes might be replaced by trim tanks and the forward hydroplanes sited at the neutral point, this is impracticable, for the reasons : (*a*) space inside a submarine is at a premium, and the trim tanks and pumps to move the water would be unwelcome ; (*b*) the hydrostatic moments produced by moving water inside the boat would be dwarfed by the hydrodynamic moments which could be supplied by after hydroplanes at other than very low speeds ; (*c*) it would be impossible to move the water fore and aft at anything like the speed of operation achievable with after hydroplanes.

Monsieur S. Bindel (France) : The problems of stability and control have assumed increased importance with the building of high speed submarines. Dr. Nonweiler has succeeded in avoiding mathematical developments ; but I regret that he did not give, in an appendix to the paper, the two or three important equations which are the basis of this work. I would refer to the three interesting points he considers in the paper, the " neutral point," the " trim point " and the " manoeuvre point." If the neutral point is well known, that does not seem to be the case with the trim point, where a force applied gives no change of depth. However, this property has been known for a long time, since it was discovered in relation to airships by an Italian officer, Crocco, in 1907 ; and a year after that it was introduced for submarines by Maugas, Ingenieur en Chef du Genie Maritime, in the French Navy. But, so far as I am aware, it seemed to have been forgotten for many years and was re-introduced during the last war by Dr. Grimm, in Germany. Its role is important because it is largely responsible for the existence of two couples of planes on submarines. As stated in the paper, there exists a speed, relatively low, at which the trim point passes through the centre of pressure of the rear planes, and it is then impossible to change depth by means of these planes only, and it becomes necessary to have forward hydroplanes. At higher speeds the trim point comes in the vicinity of the forward planes, which are consequently ineffective for changing the depth of the submarine. Then the control of the submarine can be effected only by means of the rear planes. That is why on some submarines the forward planes are retracted at high speeds.

I do not agree completely with the author concerning the optimum stability. In my opinion a high degree of stability is useful, especially for high speeds. In this case the metacentric stability is negligible and the motion of a submarine in the vertical plane is identical to the motion of a surface ship in the horizontal plane. Although sometimes there may be antagonism between permanent manoeuvring and stability in the case of surface ships, that is not the case with a submarine. This is due to the fact that the basic manoeuvre to consider is a change of heading, relatively small, and not a permanent one. To give a trim of 30 deg., for example (which is probably the practical maximum), the rear hydroplanes are in all cases more than sufficient,. Consequently, if there is a problem, it is not in the final stage of the manoeuvre, but in the intermediate one. A high stability is thus favourable to obtaining a high rate of change of heading.

Dr. W. Muckle : I think the author has said that at zero speed the banking would be zero ; but I still think there may be some banking due to the motion of the water around the ends of the ship. In his explanation of the effects of cross-coupling damping he indicated that the influence of the centrifugal force will increase the angle of incidence. Will it not be true also that the mere inclination of the ship might increase the disturbing force and the disturbing moment, or is the moment generated by putting the submarine opposed to the original direction of the motion?

Again, is the submarine body inherently stable or unstable when you displace it from the equilibrium position? Is the cross-coupling damping effect the same thing as the coupling between pitching and heaving? Even in still water, if the body starts heaving it will develop pitch, and vice versa. What are the disturbing forces for a submarine? I presume there are wave forces, which will diminish very considerably as the depth below the surface increases.

(*To be continued*)

Hawthorn Combined Mine

One of the largest projects carried out by the National Coal Board to date is the Hawthorn combined mine scheme in the Durham Division No. 2 Area. The British Reinforced Concrete Engineering Company, Ltd., was approached by the N.C.B. to act as engineers for the civil and structural engineering works in connection with the scheme and in this article notes are given of some of the work involved in the project.

ONE of the large projects which has been carried out in connection with the modernisation plans of the National Coal Board is the Hawthorn combined mine scheme in the Durham Division No. 2 Area. For this scheme the British Reinforced Concrete Engineering Company, Ltd., acted as engineers to the N.C.B., and we recently received from the company particulars of its part in carrying out the project. The scheme was described in some detail in our issue of November 18, 1960, and from the firm's notes we have selected some sections of general interest in connection with the civil engineering side to give an impression of the work involved. It should be recalled that under the scheme a new shaft was sunk at Hawthorn and connected by an underground haulage system at two levels with the workings at Murton, Eppleton and Elemore collieries. The whole output of these collieries is now raised at Hawthorn.

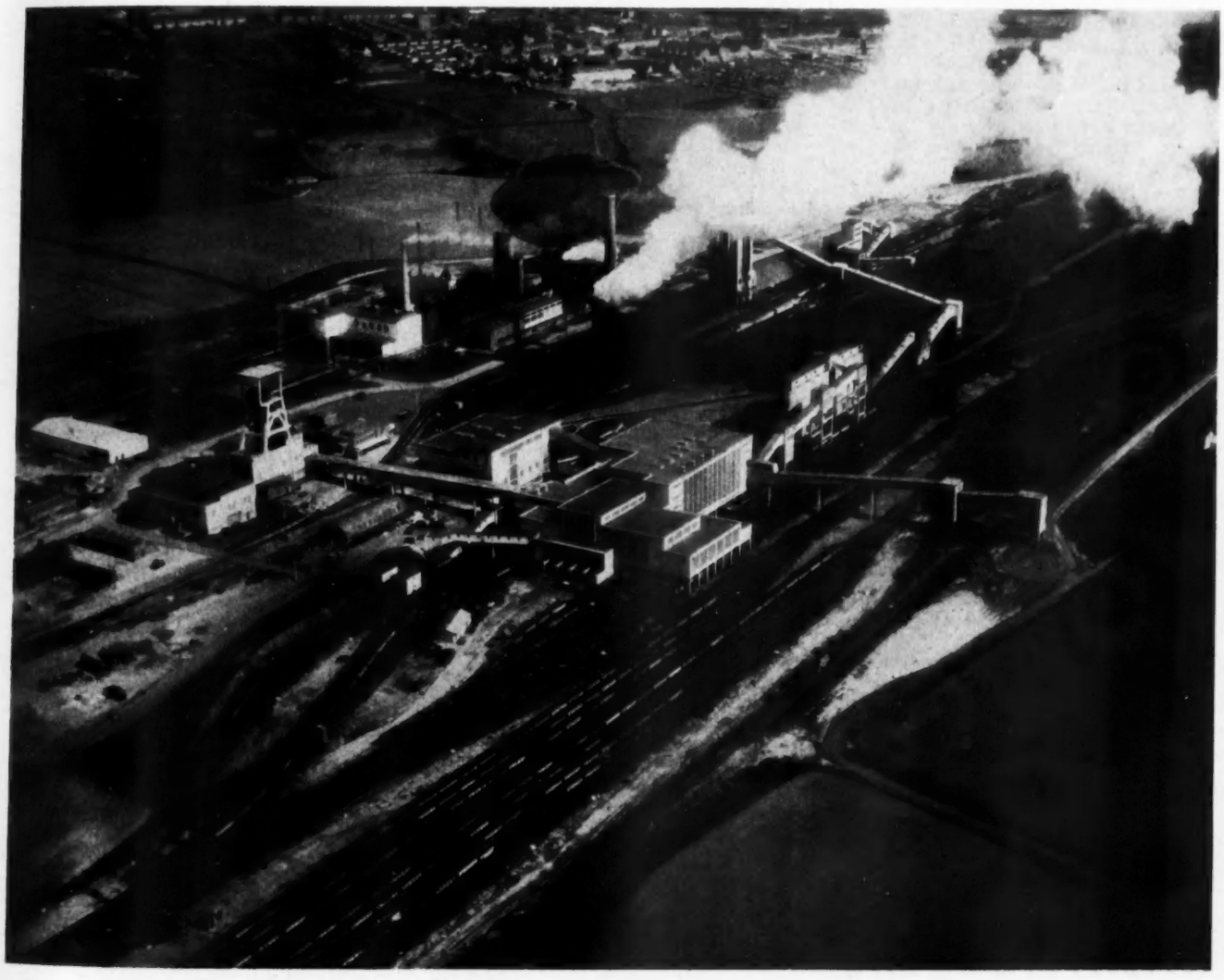
Investigation of the 132 acres site was carried out at the sites of the headframe, raw coal bunker and at the washery building. Information was also made available from a soil report covering the area of the coke ovens and by-products buildings. The soil consisted of glacial deposit comprising clay, silt clay with pockets of silt, sand and gravel occurring as hoggin. Before the earthworks contract commenced the soil report indicated that a large quantity of hoggin could be expected. Unfortunately, as the earthworks proceeded, this proved to occur only in isolated pockets and runs, silty clay tending to make up the bulk of the cut and fill—this characteristic necessitated blinding the rail formations in red shale and for a more extensive and flexible system of track drainage than previously envisaged.

The bearing capacity varied from a little below 1 ton per square foot to as much as 2¼ tons per square foot. After some consideration it was decided to use spread foundations at the appropriate pressure for all the buildings. In the area of the raw coal bunkers it was at first thought that piles would have to be resorted to but a raft design was proved to be more economical in this instance and was adopted.

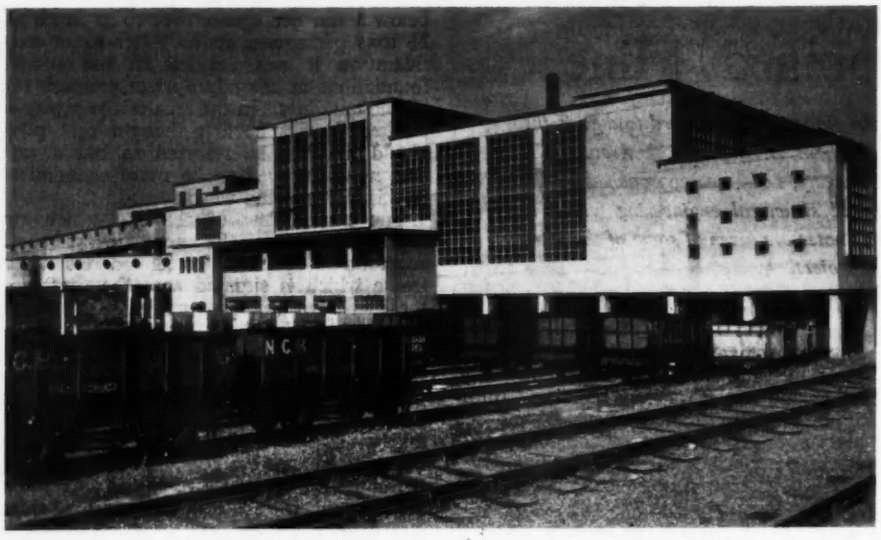
The aerial view of the site which we reproduce shows the new upcast shaft surmounted by a reinforced concrete headframe which is situated near the centre of the site. The coal preparation plant lies at the south of the shaft, to the east the coke works and coke stocking area, and to the west the coal stocking area and a 2,500,000 gallon reservoir. The gas purification plant and boiler-house are placed to the north and north east of the shaft. The N.C.B.'s mineral railway from Seaham runs along the southern boundary of the site to South Hetton where it connects with British Railways, Sunderland and Hartlepool Branch. Two independent systems of railway sidings are provided, one dealing separately with empty and full trains of coke wagons and the other similarly with coal.

Shaft

Sinking of the shaft was commenced on July 16, 1952, and coal first passed through the washery to the coke works on August 31, 1959. The sinking and walling of the



Surface installations at the Hawthorn combined mine



Coal preparation plant building

shaft were carried out by normal methods from the bottom of the shaft collar to a level approximately 260ft below ground surface. It was known that a layer of water-bearing sand 40ft thick existed between the level 369ft and 410ft below ground surface and evidence of water penetration into the overlying strata was proved up to 276ft below surface.

It was decided to install a special lining over the affected length starting 260ft and extending to 490ft below the surface, thus providing an overlap of 16ft at the top and 80ft below the length where water was known to exist. To carry out the sinking and lining the ground was frozen over the 230ft concerned. Above the 260ft level the shaft diameter was increased locally so that freezing tubes and refrigerating machinery could be accommodated in the shaft. Freezing was completed by the end of October, 1955, and the sinking through the frozen ground commenced in early November.

In preparing the design of the shaft wall, allowance was made for it to withstand the head of water indicated, increased as necessary for the effect of the running sand. In addition to this uniform radial pressure the bending moments which might occur due to uneven pressure during thawing of the ground were investigated and it was decided that these would be covered by providing sufficient additional strength in concrete and reinforcement to resist the effect of 1 ton pressure per square foot extra acting on any diameter. The concrete wall was made 2ft 9in thick, but in the calculations the outside 5in of concrete was ignored as it was thought that the concrete in contact with the frozen ground would possibly be imperfectly hardened.

The concrete was a closely controlled 1:1½:3 mix; test cubes were made at frequent intervals to prove the specified strength of 3750 lb per square inch at twenty-eight days. The bulk of this work was done in severe wintry conditions and the aggregates and mixing water were heated as necessary to ensure that the temperature of the concrete when placed in the shaft was not less than 60 deg. Fah. As a further precaution against the weather conditions and the effect of the frozen ground in the shaft, "Evoset 101 TS" was added to the mixing water at the rate of 1 gallon to each 8 gallons of water. The 235ft length of shaft was sunk and walled in four lengths starting at the top, the lengths being 50ft, 45ft, 70ft, and 70ft.

The 22ft internal diameter shaft collar wall was thickened below ground level to form a capping beam and also tied to the headframe columns. The headframe is a monolithic reinforced concrete frame structure, standing 100ft above ground level to the top of the pulley platform, there being a 29ft 6in lifting gallows above this level. The lower portion of this headframe is an integral part of the heapstead building, and it is built on isolated foundations adjacent to the shaft collar.

Each of the duplicate winders is housed in a separate compartment 52ft long by 46ft wide covered by twin shell roofs each with a chord-width of 26ft and span of 46ft. This shell is 2½in thick curved to a radius of 20ft. A travelling crane of 15 tons capacity is provided over each winder and to reduce the height of building as much as possible the shell roofs were designed without valley beams. The edge beams, on the lines of the walls, were deepened and provided with lips at the bottom on which the crane rail is seated. The walls of the winder house are of reinforced concrete 6in thick with 24in square and 12in square subsidiary columns.

Raw Coal Storage Bunker

Each of the four compartments of the bunker used for raw coal storage contains 1000 tons of coal, and can be filled and emptied independently. This structure is 120ft 9in by 94ft 9in overall and its highest point is 65ft above ground level. Each compartment has vertical walls 17ft 6in high with a trough bottom 15ft 6in deep. The sloping sides of these troughs are inclined at 49 deg. to the horizontal and no internal diaphragms or cross beams have been used in the bunker compartments, the troughs being clear from end to end. All loads are carried to the columns by the trough bottom and vertical dividing walls acting in combination as deep beams. The intermediate columns under the dividing walls caused a complication in the design due to the uncertainty of load distribution between these columns and those at each end. The assumptions made in the analysis were confirmed by the behaviour of a model.

Above the bunkers is situated the conveyor floor with a roof at two levels to give extra headroom at one end where conveyors cross at right angles.

Below the bunkers, with a clear headroom of 10ft 6in, is a further conveyor floor, level with the ground, on which travelling "Sherwen" feeders receive the coal from the hopper openings and transfer it to conveyors feeding the washery. The main columns supporting the bunkers are 3ft 3in square and each carries a load of 650 tons, the whole of the structure standing on a cellular raft with an overall depth of 6ft 3in. The base slab of this raft is 24in thick and the upper slab (which supports the "Sherwen" feeders and conveyors) is 7in thick. A system of main and secondary beams distributes the column loads, those along the south side of the raft beams deepen to 12ft 9in and form the wall of a conveyor pit.

Foreign Coal Hopper

In the event of a breakdown in the plant it may be necessary to divert the raw coal to the stacking ground. Should a fault develop underground or in the winding of coal, supplies may have to be taken from other pits. For these and other purposes a ground hopper, over which runs a rail track, is provided. Bottom-dump wagons can be used to feed the coal into this hopper and thence by a system of conveyors into the washery.

At this site investigations had indicated that water bearing strata might be encountered at any point. The design for the substructure of the hopper, which extended 30ft below ground level, took account of the possibility of external water pressure and the pit was of the usual rectangular shape. This design would have needed the use of sheet piling to be certain of holding running sand likely to be encountered and it was therefore decided, in conjunction with the contractor, to change the shape of the lower pit from rectangular to circular.

Excavation was first made to a depth of 7ft and at this level an open-ended cylinder 28ft inside diameter with 18in thick walls was constructed to a height of 22ft. The bottom edges of the walls were shaped to provide a cutting edge. Internal excavation was then carried out by grab and the cylinder sank under its own weight to the required level. Construction of the base slab, for which splice bars had been left from the walls, was much hindered by the large flow of water that had to be kept in check. When this slab was eventually completed together with its roof slab, which filled the space between the circular pit and the rectangular hopper, the opening into the conveyor trench was broken through. In constructing the cylinder the required opening for the trench entry had been formed but filled in with brickwork reinforced in the mortar joints with bars which lapped with the reinforcement in the cylinder. During sinking, therefore, and until completion of the slabs, the external pressures were resisted by ring compression and no elaborate trimming of the opening was required.

Coal Preparation Plant Building

The coal preparation plant building, which is 274ft long, 190ft wide and 69ft high at its highest end, is constructed entirely in reinforced concrete. The lowest storey is built largely over railway tracks, the 14ft spacing of which determined the spacing of columns in one direction; in the other direction the spacing of columns varies considerably, averaging 16ft but increasing at one end to 24ft. The roofs are water proofed with roofing felt on 1½in minimum vermiculite screed. The screed was used partly to provide fall, but its main purpose was to reduce the variation in temperature of the roof from summer to winter since the building is of a much greater size than is usually built without expansion breaks. In the early stages it was thought that some

joints would be needed, but the complications arising out of their provision was such that their abandonment was decided upon. It was considered that the large areas of roof would be the main source of expansion and contraction movements and the insulation was added to reduce these movements.

All of the work described was designed by the British Reinforced Concrete Engineering Company, Ltd., and the main contractors for the various sections of the work were : shaft collar, Sir Robert McAlpine and Sons, Ltd. ; headframe, Henderson Brothers (1936) ; culverting of watercourse, R. T. Haley and Co., Ltd. ; structures, earthworks, drainage and site services, Dowsett Engineering Construction, Ltd. ; access road, George Wimpey and Co., Ltd. ; railway sidings, T. W. Ward, Ltd. ; shaft sinking and lining, Blandford Gee, Ltd. ; shaft freezing, Foraky Boring and Sinking Company, Ltd. ; coal preparation plant, The General Electric Company, Ltd., which also supplied the two winding engines ; Metropolitan-Vickers, Ltd., installed the remaining equipment in the winding engine house ; and the skip handling equipment in the shaft was supplied by Head Wrightson, Ltd.

Roads for a New Town

CUMBERNAULD NEW TOWN provided a background for the discussion held by the Traffic Engineering Study Group at the Institution of Civil Engineers on April 20. A paper on the traffic planning and road design for the town, now under construction 14 miles north-east from Glasgow, was presented by C. P. Crow, P.Sc., A.M.I.Mun.E., A.M.I.H.E., senior assistant engineer, Cumbernauld Development Corporation. Mr. O. A. Kerensky was in the chair.

Cumbernauld's 4180-acre site is hilly, much of it being too steep, or otherwise unsuitable, for development. The town proper, with a population of 50,000, will occupy the broad hogsback of the principal hill ; this is made possible by a relatively high residential density—ninety persons per acre, compared with thirty-five to forty in other new towns. The town centre will be highly compact. Indeed, at the meeting, it was likened to the upper-works of a giant ocean liner with, down below, a road passing through the ship from end to end. This road—being a motor road—will be without frontage development ; slip roads from it will lead into the service areas and parks, from which people will be able to gain access, by staircase, lift or escalator, to the upper, exclusively pedestrian, business levels. One speaker, who had visited the site, remarked that already the absence of frontage development along the roads into, through and out of Cumbernauld, which are all motor roads with controlled access, contrasts strongly with what one sees when driving into an ordinary town ; at first it may seem like coming in by the back entrance, but this is an essential feature of a town designed for the motor vehicle.

Within the periphery of the designated area there are three main industrial areas, also a number of villages and a new village site. Ultimately, the villages will be developed to contain 20,000 inhabitants, bringing the overall population to 70,000. The meeting was invited to reflect that throughout the country the cost of delays and accidents on the roads amounts to at least £690 million a year, or £938,000 per 70,000 head of population. Accordingly, the £3,500,000 to be spent on Cumbernaulds 11½ mile road system (including ten two-level intersections) will be saved in less than ten years if it results in a halving of the delays and accidents within the area compared with the national average. It went undisputed that this will be achieved ; the meeting was more interested to discuss the methods used in planning the system.

There was general approbation for the Corporation's decision to entrust the planning to a closely-knit team, under the technical leadership of one man—the late Mr. A. K. Gibbs. Engineer, town planner, architect, traffic engineer and landscape architect had all played their part. The road system had evolved gradually from an initial, tentative plan, of which very little now remained. The changes had resulted mainly from ever closer analysis of the " desire lines " of the population, in the evening rush hour, forecast fifteen to twenty years ahead. The principal data adopted by the team included the following items, alongside each of which is given (in brackets) the comparable figure reported to the meeting as the actual present-day experience of Crawley New Town : Cars per family 0·7 (0·33) ; proportion of population employed, 50 per cent (46). Their mode of travel : public transport P.S.V., 41 per cent (18) ; car driver or motor-cycle, 26 per cent (19) ; car passenger, 13 per cent (10) ; on foot, including a very few cycles following pedestrian routes, 20 per cent (foot 23, cycle 30). Proportion of commuters, in employment elsewhere, matched by equal reverse commuting from elsewhere, 20 per cent (10). Proportion of commercial and other extraneous vehicles in the rush-hour traffic, 20 per cent.

By means of slides Mr. Crow was able to show the close relationship between the adopted road plan and the desire line pattern, modified to keep local through traffic from passing through the town centre unnecessarily. He showed how external traffic will be able to approach Cumbernauld by trunk road from three directions : S.W., from Glasgow (A.80) ; South, from Airdrie (A.73, joining A.80) ; and N.E., from Stirling (A.80). Three corresponding radials will branch off from two-level intersections on these trunk roads, and lead into the town, serving both external traffic and the local traffic to and from the three industrial areas. These radial roads will intersect within the town to produce the required link circuits, involving the construction of three two-level intersections of trumpet design. From the radials traffic will be enabled to reach destinations throughout the residential area by means of " distributor roads," the chief of which will take the form of a ring. The intersections between this ring road and the radials will include three two-level roundabouts and a partial cloverleaf. The radials will be dual-carriageway, and the ring distributor 33ft single carriageway, these types of road being justified by the calculated maximum flows, at a design figure of 1000 vehicles per lane per hour. Mr. Crow explained that this provided a margin, and the limiting factor would be the capacity of the intersections. The greatest flow is expected to occur on the Airdrie radial—3100 mixed vehicles per hour.

Is this lavish? One speaker remarked that the design figure of only 1000 v.p.h. per lane would guarantee high journey speeds. He felt that those concerned had been canny to get " the full treatment " for a compact town in which people would not need to go more than 1½ or 2 miles to work, walking by the separate pedestrian ways. On the other hand it was suggested that the number of cars had been underestimated at 0·7 per family, and bus usage overestimated at 41 per cent. There was no information on the proposed bus services beyond a report that the Scottish Bus Group seems confident of meeting the situation when it arises ; it has a monopoly. There might well be scope for moving-sidewalks, the meeting was told, but they are unauthorised.

Car parking in the industrial areas is planned on a scale of 1 per 3 employees (at Crawley, in 1960, it amounted to 1 per 5·2 employees). There are indications, the meeting was assured, that firms are fully alive to this problem and will meet it satisfactorily, in their own interest, though the authority will be prepared to organise joint parks for the smaller firms, if required. The meeting was reminded that there will be much employment within the town centre : commercial firms, from Glasgow and elsewhere, will migrate into office accommodation there, it is hoped ; the aim is not only industrial decentralisation, but also commercial—and office accommodation commands a good price! It was stated that in Crawley New Town the employment amounts to 15,200 in the local industrial areas, 4300 in the town centre, and 5300 in the neighbourhood centres ; the last-mentioned will have no precise counterpart in Cumbernauld owing to its non-adoption of the conventional " neighbourhood unit."

From Crawley, too, there came a word of warning about the difficulty, under present legislation, of ensuring that the roads will be used in the manner planned. For instance there is to be no frontage development along Cumbernauld's 33ft ring distributor road ; side roads (" development roads ") leading off it will give access to the groups of houses. The intention is presumably to preserve free-flow for motor traffic on the ring road, but this is likely to be unenforceable, despite the erection of ugly " no waiting " signs along the road. In answer it was admitted that this road will be somewhat over-wide for its purpose ; apart from occasional unidirectional flows of 1000 v.h.p. at one point, the maximum flow on it has been calculated to be 700 v.p.h. two-way ; its width will permit protected bays to be provided for right-turning traffic ; and it will have shoulders, on which vehicles will be able to draw up, if necessary. The radial roads will be securely fenced.

Reverting to the planning, one contributor to the discussion pointed out that great reliance could be placed on the Cumbernauld desire lines ; they related to genuinely possible journeys between sectors of the residential area and obvious destinations, few in number. In an ordinary town the wide scatter of destinations would render this type of planning more complicated, and perhaps unreliable. It would be an interesting experiment to apply the Cumbernauld method, off the map, to an existing town, and then make spot checks of the actual traffic to determine the degree of accuracy achieved. That this problem was not the only more complicated one in an existing town or city was made clear by several speakers who contrasted development with redevelopment ; beyond doubt, virgin land had rendered the project under discussion " an exciting exercise " for all those fortunate enough to be concerned in it. The meeting ended with an expression of the Group's appreciation of its opportunity to discuss a town in process of being "built around the car."

SHORTER REPORTS

Plans for Second U.K. "Scout" Satellite

THE British National Committee on Space Research, the U.K. Steering Group on Space Research and the U.S. National Aeronautics and Space Administration have agreed on the scientific instrument payload for the second U.K. "Scout" satellite to be launched by N.A.S.A. The scientific instruments, as in the first U.K. "Scout" satellite (S-51), will be designed and provided by U.K. scientists.

The International Committee on Space Research (C.O.S.P.A.R.), which has been meeting at Florence and under whose aegis the offer to launch satellites was first made, has been informed of this extension of the U.K./U.S. joint programme.

The experiments are designed to measure radio emissions from the galaxy at wavelengths too long to penetrate the earth's atmosphere; to measure the vertical distribution of ozone in the regions of the atmosphere in which it is being formed; and to measure the number and size of fine dust particles encountered by the satellite. In addition, the galactic radio equipment is designed to gain information on the electrical condition of the high atmosphere.

It is expected that the satellite will be launched in about two years' time. The orbit will probably pass over the United Kingdom and the United States and it should be possible to receive radio information both in these countries and at stations in the British Commonwealth.

It will be recalled that the Chance-Vought "Scout" launcher is a four-stage rocket system using solid propellants. It is expected that the satellite orbit will range between 300km and 2000km from the earth.

A detailed description of the experiments in the second satellite follows:

1. *Galactic Noise.*—The measurement of galactic noise in the frequency range 0·75-3 Mc/s, and the exploration of the upper ionosphere (Dr. F. Graham Smith, Mullard Radio Astronomy Observatory, Cavendish Laboratory, University of Cambridge).

Dr. Smith will have three objectives:

(*a*) To measure the intensity of the galactic background at as low a frequency as possible under known conditions of receiver sensitivity and under known conditions of ionospheric effects on propagation and aerial impedance.

(*b*) To watch for temperal or spatial variations of galactic radiation.

(*c*) To explore the electron density in the upper F region.

2. *Atmospheric Ozone.*—The measurement of atmospheric ozone by two methods: (*a*) a spectrum scanning method; (*b*) a method in which a broad band of the spectrum is observed (Dr. R. Frith, Dr. K. H. Stewart, Air Ministry, Meteorological Office, London).

Dr. Frith's experiment will have as its main objective the measurement of the vertical distribution of ozone in the earth's atmosphere as often as and in as many places as possible. These measurements should add to our knowledge of the processes forming and destroying ozone, of the air motions which distribute it and of the effects of ozone on the thermal equilibrium of the upper atmosphere. Measurements will be made of the intensity of the radiation received from the sun at selected wavelengths in the ozone absorption region in the ultra-violet at times when the satellite is entering or leaving the earth's shadow and the solar rays have to pass through the earth's atmosphere to reach the satellite.

3. *Micrometeorite Flux.*—The measurement for the micrometeorite flux (Dr. R. C. Jennison, Nuffield Radio Astronomy Laboratories, University of Manchester, Jodrell Bank, Cheshire).

Dr. Jennison's experiment has as its objective the detection and measurement of micrometeorites encountered by the satellite. He will use a technique in which the holes formed in a thin metallic film by the impact of micrometeorites will be detected by an optical method. Sunlight passing through the holes will fall upon a photosensitive strip of solar cells and give a signal from each hole in turn from which the number and size of the holes, and hence of the micrometeorites, can be deduced. The sensitivity is such that the holes formed by the particles, 1 micron in diameter or greater, may be detected.

Report on Welsh Water Resources Shows Exploitable Surplus

A REPORT entitled "The Water Resources of Wales" (H.M. Stationery Office, Price 5s.) has been published; it is the work of the Welsh Advisory Water Committee (chairman: Alderman Lloyd Owen of Montgomeryshire) which the Minister of Housing and Local Government and Minister for Welsh Affairs appointed in February, 1958, to advise him.

Wales has an exploitable surplus of resources over demand which lies somewhere between 235 and 800 m.g.d., according to what system of development of resources is adopted, the report states. The committee, which consisted of persons from different parts of Wales with a special interest in water questions, but not themselves engineers or technical experts, has made a careful study, the Ministry states, of the technical data available to it, in particular a hydrological survey of Wales and Monmouthshire carried out by the Ministry's engineers in 1957. Dividing Wales into five zones, each containing two or more major river basins, it finds that only one of these zones (the south-east) has a serious prospective deficiency of water, and is of the opinion that the first claim on the large surplus of water in the rest of Wales must be to meet the deficiency in the south-east zone. It considers that the part of the surplus which can be most easily used to supply areas in England which are short of water is in the basins of the Severn, Wye and Dee. The Committee reports that the upper regions of these three rivers can be made to yield far more water than is likely to be needed in the parts of those basins which lie within Wales.

The report stresses that this should be done by means of regulating reservoirs (i.e. water for consumption is abstracted from the river lower down, and not by pipeline from the reservoir itself). The committee has considered a large number of possible reservoir sites in Wales, applying to them the tests of geological structure, effect on agriculture, disturbance to existing communities, effect on amenities, and cost involved. It places them in four broad categories of acceptability.

The committee suggests that rural areas where large reservoirs have been sited have not always received adequate returns, and that there is a strong case for a system whereby a material benefit would be received by such areas in addition to the extra revenue they receive in the form of rate income.

In compiling its estimates of future demand for water the committee notes that "between 1948 and 1958 manufacturing in Wales grew almost twice as fast as in Great Britain," and feels it safe to assume that "the Welsh economy is now securely launched on a long era of expansion." It believes that "in a period when water will become relatively more scarce, a country of heavy rainfall will have an increasing comparative advantage" and that "this very fact will make Wales a more favourable location for water-seeking firms and for agricultural irrigation."

Power Cable Link between Kintyre and Jura

THE North of Scotland Hydro-Electric Board has decided to have submarine cables laid from the mainland grid system, as the most convenient way of supplying the growing demand for electricity on the island of Islay. Besides reinforcing the existing supply network on Islay these cables will bring electricity to the island of Jura. That island is situated between Islay and the mainland.

Islay has a load of about 2000kW, which is met by diesel generation at the Bunanuisg power station at Bowmore, where there are three 600kW and two 265kW sets. Diesel generation is not cheap on Islay as there is no deep water pier at Bowmore and fuel oil is delivered at Port Ellon and transported over about 12 miles of road to the generating station. The possibility of a mainland connection to Islay was examined when the 33kV system on the Argyll mainland was reinforced by building a 132kV line along Loch Fyneside to a 132/33kV bulk supply point at Port Ann near Lochgilphead. A detailed analysis showed that by 1961 it would be no more expensive to take supply from the mainland over a 33kV extension to Islay than to continue diesel generation on Islay. After 1961 the mainland connection will become progressively more economic than diesel generation.

Initially the first stage of the submarine connection scheme will consist of a single-circuit overhead line from the Port Ann substation to Keills near the mouth of Loch Sween on the west coast from where the submarine cables will be laid to the island of Jura. The connection will be made up of a submarine cable crossing of 6½ miles from the mainland to the island of Jura, another of 1¼ miles from Jura to Islay and 42 miles of overhead woodpole line. Between the mainland and Jura the maximum depth is 84 fathoms. For this circuit, therefore, it was decided to use two three-core 0·1 square inch gas-filled 33kV cables. The maximum pressure of water on these cables at this depth is equivalent to 224 lb per square inch and the internal gas pressure will be maintained at 250 lb per square inch. For the connection between Jura and Islay two 0·1 square inch three-core preimpregnated paper insulated HSL solid-type 33kV cables will be used. This crossing is in relatively shallow water. This, together with the remote location of the landing sites, decided the use of this type of cable for this crossing.

Use will be made of 3 miles of existing 33kV line out of Port Ann substation as well as 5 miles of 11kV line between Tayvallich and Xeilis which is to be uprated to 33kV. On Islay a 33kV overhead line will run from the submarine cable landing point to Bowmore. The route across Islay will allow reinforcements to be readily carried out to the 11kV network where this is required. The new line will terminate at the Bowmore generating station with a connection to the busbars through a 3·5MVA transformer.

Jura has no electricity supplies at present, but opportunities will now be created for consumer connections to the 33kV line. The possibility of a small hydro development on Jura will also be investigated.

The Board has placed a £100,000 contract with the B.I.C.C. Group for the supply and installation of the submarine cables referred to above. The cables have been made by B.I.C. (Submarine Cables), Ltd., and they will be installed early this summer by the submarine contracts department of B.I.C. Construction Company, Ltd.

Lloyd's Shipbuilding Returns

LLOYD'S Register of Shipping has issued its Shipbuilding Returns for the first quarter of 1961. Work in hand in Great Britain and Northern Ireland at the end of March totalled 249 ships of 1,610,647 tons gross and is the lowest total since December 1945. Of the total eighty-eight ships of 590,162 tons are fitting out and 161 ships of 1,020,485 tons are still to be launched. During the quarter the tonnages commenced, launched and completed amounted to fifty-eight ships of 295,823 tons, sixty-five ships of 343,222 tons and sixty-seven ships of 381,162 tons respectively. These figures are better than last year's level but the tonnage of ships preparing at 816,080 tons is 127,379 tons less than the previous quarter and the lowest since 1946. Oil tankers total forty-one ships of 721,921 tons and represents 44·8 per cent of the tonnage under construction. Out of the total under construction, thirty-nine ships of 354,169 tons, or 22·0 per cent, are for registration abroad while the tonnage being built abroad for Great Britain and Northern Ireland amounted to 457,000 tons.

Abroad, excluding China, East Germany and Russia, the work in hand totalled 1223 ships of 7,115,214 tons of which Japan's share was 1,025,090 tons while the corresponding figures for Germany and Sweden were 837,086 tons and 830,056 tons respectively. Ships commenced, launched and completed during the quarter were: 421 ships of 1,701,957 tons, 366 ships of 1,494,451 tons, and 338 ships of 1,591,645 tons respectively. Of the total under construction 172 ships of 2,825,482 tons or 39·7 per cent were oil tankers. Tonnage for export amounted 2,978,372 tons or 41·9 per cent of the total building.

Throughout the world 1472 ships of 8,725,861 tons gross were under construction of which 18·5 per cent is being built in Great Britain and Northern Ireland. Tonnage building for export amounts to 3,332,541 tons of which 10·6 per cent is building in Great Britain and Northern Ireland. Oil tankers under construction at the end of the quarter totalled 213 ships of 3,547,403 tons gross or 40·7 per cent of the total. Of the steamships and motorships building throughout the world, 4,183,230 tons, equivalent to 47·9 per cent, are to be classed with Lloyd's Register.

Ultrasonic Inspection of Aqueduct

PART of the water supply for the city of Bristol is conveyed by an aqueduct 10 miles long from a spring source in the Mendip hills. The aqueduct, which was constructed for the then newly-formed Bristol Waterworks Company in 1846, starts as a cast iron main, increases in size as additional water is collected from valleys *en route*, and eventually becomes a stone-lined tunnel. At three points the aqueduct has to cross valleys, and here it takes the form of an egg-shaped wrought iron conduit, 4ft 7½in high and 3ft 6in wide at the widest point. The conduits are of riveted plate construction, the nominal plate thickness being $\frac{7}{16}$in. In their 115 years of existence the conduits had received no maintenance other than painting the ironwork and pointing the masonry support piers.

In 1959 the Bristol Waterworks Company decided to make a detailed survey of part of the wrought iron conduit section and hired ultrasonic flaw detection equipment from Kelvin Hughes (now part of Smiths Industrial Division) to measure the thickness of the plates from inside the conduit. Measurements were carried out at Harptree Coombe, on a 110-yard section of the conduit, using Kelvin Hughes MK5 equipment and a MK3 depth gauge, with a standard V.L.O. 5 Mc/s probe. Limited corrosion was revealed, the minimum plate thickness being $\frac{1}{16}$in, compared with the nominal $\frac{7}{16}$in; this would not necessarily have been uniform throughout even when new.

Further measurements were made in 1960 on another section of the conduit, using the same equipment, but with it mounted on a special trolley, which enabled the operator to work without fatigue. For the period of the test the water was turned out of the aqueduct, and small stones, silt and other debris was brushed from the invert of the conduit. A series of spots, at regular intervals, was chosen for examination, in such a way as to be representative of the complete length. The spots were thoroughly cleaned by wire brushes and, where the surfaces were rough, were ground to produce a flat surface about 2in square. A film of "Polycell" paste was applied to the cleaned spots to provide a good acoustic coupling for the probe. The method used was completely satisfactory, and enabled the survey to be completed, and the aqueduct to be put back into service in ten days.

[Reply Card No. E7112]

Thermal Efficiencies of C.E.G.B. Power Stations

IMPROVED efficiency of generating plant in power stations of the Central Electricity Generating Board has resulted in a saving of nearly £3,000,000 in fuel costs in 1960. The average overall thermal efficiency of the Board's power stations was 26·71 per cent during 1960 compared with 26·36 per cent during 1959. Nearly one-third of the 102,891 million units supplied from all the stations was sent out by the twenty most efficient stations: these stations, tabulated below, had an average thermal efficiency of 31·9 per cent.

Station	Thermal efficiency per cent
Blyth "A," Northumberland	34·28
Agecroft "C," near Manchester	34·14
High Marnham, near Tuxford	33·20
Drakelow "B," near Burton-on-Trent ...	33·03
Castle Donington, Leicestershire	32·70
Ferrybridge "B," near Castleton	32·60
Staythorpe "B," near Newark...	32·35
Willington "A," near Derby	31·79
Northfleet, near Gravesend	31·30
Tilbury "A," near Grays, Essex	30·90
Belvedere L.P., Kent	30·77
Marchwood, near Southampton	30·75
Drakelow "A," near Burton-on-Trent ...	30·71
Aberthaw, near Barry	30·63
Rogerstone, near Newport, Mon.	30·37
South Denes, near Great Yarmouth ...	30·25
Meaford "B," near Stone	30·15
Stella South, near Blaydon, Co. Durham	30·14
Wakefield, Yorks	30·14
Stourport "B," Worcs	30·04

A comparison with the corresponding results for 1959 (THE ENGINEER, May 6, 1960, page 786) shows that the first two positions in the table are unchanged; that High Marnham is now third, having displaced Castle Donington which drops to fifth; that Drakelow "B" moves up from fifth to fourth place. Portishead "B" Stella North, Littlebrook "B" and Hams Hall "C" are no longer among the top twenty stations. For the first time all the stations listed in this table have thermal efficiencies exceeding 30 per cent.

An Appraisal of Building Costs

THE present range of building materials and techniques has greatly increased freedom of design in building construction, but the variety has increased the difficulty of determining which combination provides the best value for money. This was one of the points made by Mr. P. A. Stone, an economist at the Building Research Station, in an address delivered to a meeting of the Royal Institution of Chartered Surveyors last week.

"Value for money is the useful everyday concept by which people determine their purchases," he said. "Often the concept is applied very roughly, in the absence of adequate information, but it will generally be agreed that buildings absorb far too great a part of our resources for such crude methods to be acceptable, and a systematic approach is essential." He went on to explain the concept of "costs in use," in which the initial costs and the running costs of a building were reduced to a single figure of annual cost. Using this method, the Building Research Station had made studies of the economics of various building designs, and in his paper, he gave examples of its application to factory design. For example, one cladding which initially cost 20 per cent more than an alternative had "costs in use" of little more than a half those of the alternative.

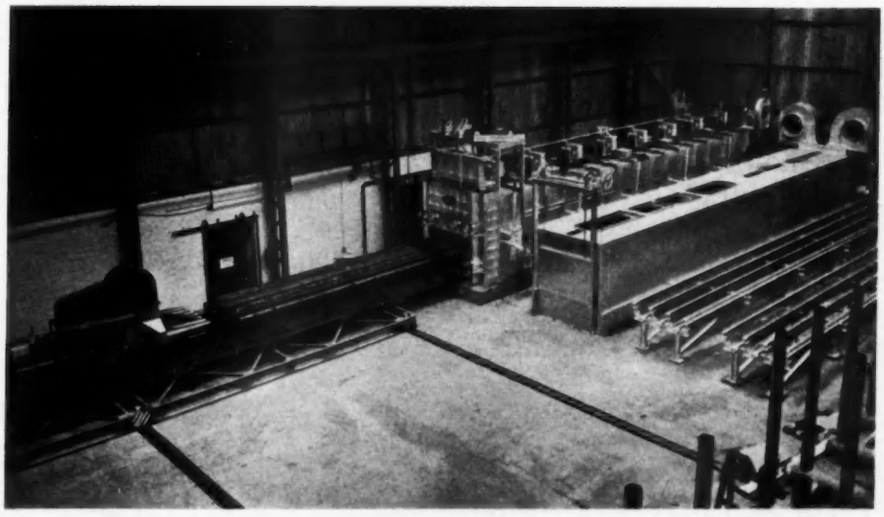
Finally, the speaker stressed that while the use of a formal technique and the inclusion of running costs may appear to increase the difficulty and uncertainty of cost planning, in reality it only exposes difficulties and uncertainties already present.

Heat Treatment Plant for Tubes

A LARGE, atmosphere controlled, batch furnace and charging machine for the specialised heat treatment of tubes has been supplied for the Bromford Works of Stewarts & Lloyds Limited, by Metalectric Furnaces, Ltd., Smethwick, 40, Staffs. This furnace, which is illustrated below, has an electrical rating of 1000kW, a maximum operating temperature of 1000 deg. Cent. and is capable of accepting a 15-ton charge of tubes having a maximum length of 50ft. To achieve the close temperature uniformity required in this application, the heavy-duty electric heating elements are controlled in five separate sections, or zones, along the length of the furnace chamber. To further assist temperature uniformity during heating and cooling air circulation fans are mounted in the heating chamber roof.

To cover the wide range of critical cooling speeds required for the various tube-steels the furnace is arranged for cooling with or without protective atmosphere, the charging machine has means of air-blast cooling and a cooling chamber capable of accelerated or retarded cooling is incorporated. The necessary protective atmosphere is provided from a nitrogen generator having an output capacity of 3500 c.f.h. This generator produces nitrogen by the combustion of town's gas and air and then removes both CO_2 and water vapour, after combustion, to give a resultant atmosphere of approximately 99 per cent pur nitrogen.

[Reply Card No. E7115]



Atmosphere controlled batch furnace and charging machine for the heat treatment of tubes

SHORTER REPORTS *(continued)*

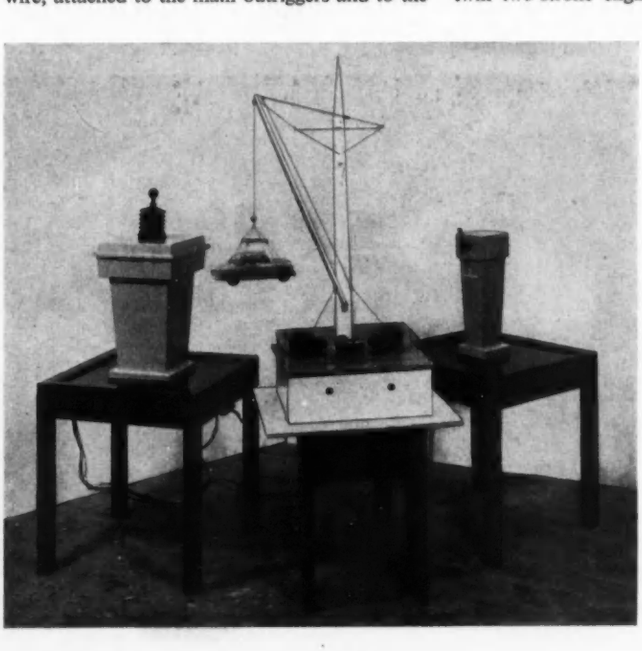
Cargo Handling

FILMS demonstrating cargo handling devices were recently shown by MacGregor and Co. (Cargo Handling), Ltd., of 5 Camomile Street, London, E.C.3. and one was concerned with the universal bulk carrier. This is a ship of special design to enable a full deadweight of any dry cargo to be loaded in bulk whatever the density with optimum metacentric height. The carrier is of conventional design only in so far as it has a single deck and has machinery arranged aft. There are a number of main holds, and with these are associated a number of partial 'tween deck compartments bounded at the ends by transverse bulkheads and divided into wing and centre compartments by two longitudinal bulkheads. These three compartments are available to carry cargo or water ballast, while the wing spaces are suitable to take grain or vegetable oils. The two longitudinal bulkheads in the 'tween deck holds are continued through the main holds as deep girders below the upper deck. They act as grain feeders and serve as permanent steel shifting boards while forming a valuable member in the longitudinal strength of the ship. The main holds are arranged for discharge by grab and the shape of 'tween deck holds renders them practically self trimming. This disposition of holds permits the adjustment of the ship's trim and stability, in loaded or ballast condition, to ensure a suitable metacentric height or a fore and aft distribution of cargo to enable the longitudinal stresses to be kept to a minimum.

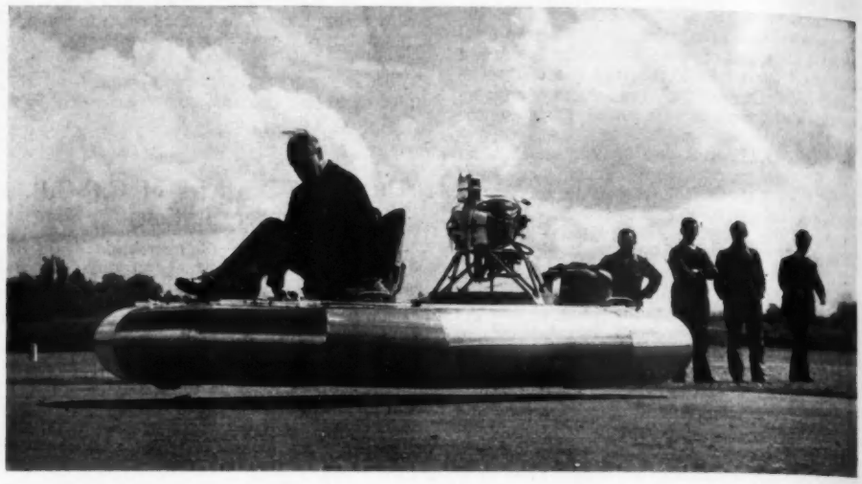
Another film showed the operation of the Hallen swinging derrick which combines the advantages of deck cranes with those of a conventional derrick. The derrick is of simple design and does not suffer from the disadvantage of limited lifting capacity which applies to cranes since loads up to 100 tons can be handled. This form of derrick can be used in association with all forms of mast or derrick post and can replace the two derricks normally used for the Union system of discharging. As can be seen from the photograph of a model which we reproduce the derrick is mounted on the centre line and supported by twin topping lifts attached to the outer ends of an outrigger. Another outrigger of bar form is fitted to the mast and mounted vertically on the centre line and this arrangement ensures that the topping lifts are kept at an angle to one another to enable the derrick to hang steady when swung out to 90 deg. over the ship's side, even when the ship has a heavy list.

Each of the topping lifts consists of a single wire, attached to the main outriggers and to the topping tackle from which the topping wire is led to a winch over a sheave on the mast and a block shackled to the derrick head. No guys are required. For operating each derrick there are three Siemens Schuckert/Donkin a.c. winches, two for topping purposes and one for cargo operation. By means of specially designed Siemens Schuckert control gear one man can operate all the derrick movements by two levers. One of the levers controls the swinging and topping movements or a combination of both by moving it in the direction in which the derrick is required to move. The derrick follows the movement of this control level, thus if the lever is moved forward the derrick is lowered and if moved backwards the derrick is topped, while movement to right or left swings the derrick in the corresponding direction. The second lever is concerned solely with the hoisting and lowering of cargo.

[Reply Card No. E7121]



Model of Hallen swinging derrick



The "Skimmer" hovering; the shallow wooden feet that protect the metal panels on hard ground are visible

Lightweight Ground Effect Machine

A SMALL ground effect machine on Cockerell principles has been built by students of the College of Aeronautical and Automobile Engineering for its designer, Mr. D. A. Robertson. The "Skimmer" is 11ft 6in long and weighs 250 lb; it is powered by a 40 h.p. Johnson water-cooled twin two-stroke engine normally included in a marine outboard propulsion unit. The engine is mounted directly above the radial flow fan, and drives it through a simple clutch in which the presser plate is distorted in the manner of a Belleville spring by arms, parallel to the axis, set around the perimeter and carrying masses at their ends. The ducting is of the simple inclined annular curtain design associated with the "Hovercraft," the shell being made of light alloy using simple curvature throughout. The radiator for the engine coolant consists of a small number of long pipes lying on the deck and joined up by nylon hose; since the thermo-syphon effect would suppress circulation, a water pump is provided. The only control, other than the throttle, is a rudder bar pivoting numerous small blades in the slot emitting the jet curtain; save for height and heading, the pilot directs the machine by leaning in the direction in which it is desired to accelerate.

We observed a demonstration of the machine at Redhill Aerodrome, Nutfield, Surrey, where the aircraft maintenance work of the College is carried out. The engine, which has automatic inlet valves and decompressors linked to the recoil starter, started easily and very readily lifted the "Skimmer" off the grass. With a normal load, it can hover at 4in to 5in, but sufficient cushion pressure is available to lift off when carrying five men (850 lb). The machine was clearly very sensitive to centre of gravity displacement—it will be seen that the pilot sits quite low in the deck—but response in yaw appeared to be very faint. Even for such a small machine as this, it appeared that the inertia dominated its motion.

Radio Compass Accessories

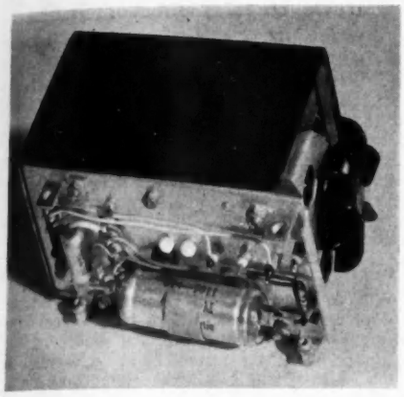
Two sub-units have been introduced by Marconi's Wireless Telegraph Company, Ltd., Chelmsford, Essex, to improve the operation of the AD7092 series of airborne automatic direction finders, and to reduce weight and power consumption. Although the AD7092 is no longer in production, some 3500 are in service and the present modifications are intended to increase their efficiency and useful life.

One of the new sub-units is a transistorised switching unit to replace the mechanical vibrator for providing the loop switching frequency. A 110 c/s balanced output is supplied to the phase-splitter driving the balanced modulator in the loop aerial circuit, and to the two-phase loop drive motor. Absence of r.f. noise makes suppressor circuits unnecessary. The circuits are protected from pulses on the 28V supply. Frequency can be adjusted by means of a tuning slug, whereas if a vibrator begins to drift in frequency it is necessary to replace the unit. The frequency is accurate to within ± 2 c/s throughout a temperature range of -30 deg. to

55 deg. Cent. and a balanced output is always obtained.

The switching unit is a direct plug-in replacement for the vibrator, and no other modifications are necessary. Models are now being evaluated by B.E.A., B.O.A.C., K.L.M., Alitalia and Capital Airlines, and the units will be available in June of this year.

The second sub-unit is a radio compass power unit for aircraft with a 115V, 400 c/s supply, providing receiver h.t. through a transformer and silicon diode bridge rectifier, with an 800 c/s nipple filter in the output. This replaces the rotary transformer in all versions of the AD7092 equipment and involves minor modifications to wiring and in the receiver backplate. In the the accompanying illustration the fan is seen



Silicon diode transformer/rectifier power unit for aircraft radio compass

which replaces that in the rotary transformer, and is driven by a two-phase induction motor. The power unit modification saves nearly ½ lb in the weight of the radio compass equipment, while static conversion improves reliability and reduces noise. This unit is also being evaluated by the airlines and will be available in June.

[Reply Card No. E7123]

Variable-Speed-Drum Truck Mixer

A TRUCK mixer/agitator made in two capacities of 4/4½ and 6/6½ cubic yards by Blaw Knox, Ltd., Rochester, Kent, is now fitted with a hydrostatic drive giving a range of drum speeds under the control of a single lever. By using the range of drum speeds, which is steplessly variable up to 20 r.p.m., the most suitable speed for charging, mixing, agitating and discharging can be selected to give an economic and rapid working cycle.

The robust welded steel main frame of the mixer assembly has a curved front pedestal which supports the drum on tapered roller bearings. Abrasion resisting alloy steel is used in the manufacture of the drum and blades and a special "shrink" blade, set at right angles to the spiral blade, imparts a "criss-cross" mixing action as the drum turns. In drawing attention to this construction the maker points out, that with a 32 per cent shrinkage from dry materials to mixed, fast shrinkage assists rapid entry of flowing materials. Water is delivered into the drum through its main bearing and is discharged at two points by self-sealing and non-clogging nozzles.

At the rear the drum is supported by two wide rollers and its drive is taken through a spur gear box and roller chain to a sprocket bolted on to the drum head. The hydrostatic power unit is driven by a power take-off and the single hand lever is used to select direction of rotation and speed. A fixed open-end charging hopper is fitted and the discharge chute which can be locked in any of three positions has a maximum discharge range of 16ft with extensions.

A single compartment or a two-compartment water tank which can be fitted deliver through meter control into the drum. With the two-compartment tank provision can be made for the use of additives to the mix or for separate flush water. A top-mounted pressure flush water tank available is operated by compressed air from the truck air-brake reservoir.

One of the new "Varispeed" truck mixers is shown in the accompanying illustration.

[Reply Card No. E7131]

Capacitor-Discharge Stud Welding

EQUIPMENT applying the stored electrical energy in a capacitance discharge to the welding of small diameter studs to plate or thin gauge metal—a process which has been available for some years in the United States—is now being made in England by K.S.M. Stud Welding, Ltd., Old Woking, Surrey. This process is characterised by a very high peak current (about 5000A) with a very short duration (about four milliseconds). It follows that the heating is extremely localised and that studs ranging from about 6BA to ¼in diameter can be welded to thin gauge metal with no marking of the underface, even when it is stove enamelled or plastics-coated. For a full area weld, penetration ranges from 0·002in to 0·01in, depending on the materials used, which include steel studs to copper, steel to brass, aluminium to aluminium, stainless steel to mild steel and mild steel to stainless steel.

The equipment, illustrated here, consists of a CD84 capacitor-discharge welding power unit connected to a "Bantam" stud welding gun by 40ft lengths of power and control cables. A twin-core cable connects the power unit, through a 13A plug to the mains supply which is single-phase, a.c. 110V–240V. The usual earthing cable is clamped to the work-table and connected to the negative terminal on the power unit.

The main components of the power unit are a bank of capacitors of about 100,000 microfarads capacitance and a power-pack to charge them, during operation, at a rate of about ten or twelve times a minute. A variable transformer in the power unit enables the capacitors to be charged to any predetermined amount depending on the size and materials of the components to be welded. In practice the capacitors are charged to a specified voltage, measured on an indicating voltmeter (see illustration) the voltage required being determined by experience or by reference to charts provided by the manufacturer. A specially designed contactor in the power unit initiates the cyclic charging and discharging of the capacitors. The power unit

Hand tool for capacitor-discharge stud welding

also contains control circuits to ensure repetitive accuracy during operation.

The welding gun as illustrated is a hand tool fitted with welding and control cable connections. The mechanism consists simply of a replaceable chuck to carry the stud; a press switch to initiate the weld; and a return spring to provide the weld pressure.

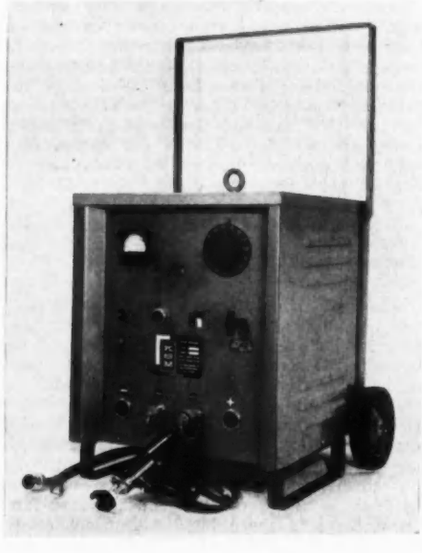
Each stud or other attachment to be welded, as supplied by the maker of the equipment, has an accurately dimensioned "pip" at the welding end. Weld consistency is largely controlled by the dimensions of this "pip" which influences the input of energy to the weld.

Welding procedure is simple. Having adjusted the variable transformer to give the appropriate voltmeter reading (e.g. 120V) and having loaded the chuck, the stud is offered to the weld position and the trigger switch is pressed. The rest of the operation is automatic: closure of the trigger switch actuates the control circuit which closes the contactor and discharges the capacitors through the "pip" on the stud in contact with the workpiece. As the "pip" carries the full discharge current it fuses and the subsequent arc between the stud and the work causes very localised melting and allows the spring pressure to complete the weld.

In the power unit, the capacitors are made in the U.S.A. but the rest of the equipment is British. The welding gun is made in Britain apart from the moulding itself which for convenience is imported from the U.S.A. The main dimensions and weights are as follows: power unit, 15in by 19in by 24in, 225 lb; gun 7½in long (with 1in stud inserted), 3¾ lb including 5ft cables. As illustrated, the power unit casing is of heavy-gauge sheet steel, with ventilation louvres, handle and rubber tyred wheels.

[Reply Card No. E7132]

Left: Truck mixer/agitator with drum driven by a hydrostatic variable speed unit



Right: Power unit for capacitor-discharge stud welding

SHORTER REPORTS *(Continued)*

Compressed Air Filter/Regulator

A FILTER-REGULATOR introduced by C. A. Norgren, Ltd., Shepston-on-Stour, Warwickshire, for use in compressed-air systems combines in the compact unit illustrated means of effective filtration and pressure regulation ; it is available in ¼in and ⅜in pipe sizes. When fitted with a transparent bowl, as shown, the unit is suitable for input pressures up to 150 lb per square inch and when supplied with a metal bowl it

Filter-regulator for ¼in and ⅜in compressed air pipe systems

takes air at up to 250 lb per square inch. Three regulating spring ranges are available and both relieving and non-relieving types of unit are supplied.

Air entering the filter section passes a deflector which imparts a swirling motion and the resultant centrifugal action deposits liquids and heavier dirt particles on the bowl wall for them to gravitate down to the lower section. The air then passes inwards through a filter element which can be one of four grades of sintered bronze (5, 10, 25 and 64 microns) or of 74 microns (200 mesh) monel screen construction. The cleaned air then passes on through the balanced regulating valve to the delivery line. Normally the units are fitted with a compound spring giving up to 125 lb per square inch regulated pressure but, if required, can be supplied with regulating springs for 0 to 50 lb per square inch.

[Reply Card No. E7141]

Facing Chuck

A FACING chuck, known as the "Titanic," has been introduced by Samuel Osborn and Co., Ltd., Clyde Steel Works, Sheffield, 3, for use with the high-speed steel screw bore cutters made by the company. It is claimed to combine the advantages of a screw thread drive with a means of quick-release and positive locking for the cutter. A cutter is made ready for use by simply screwing to hand tightness on the chuck. To remove the cutter a spanner is fitted on the chuck sleeve and on giving it a sharp blow with a mallet the

Facing chuck for screw-bore cutters

cutter is released. At this stage the spanner cannot be removed from the chuck until it is turned to restore the sleeve to the locked position.

The chuck, to be seen in our illustration, incorporates two wedges and when the outer sleeve is turned by the spanner a cam action slides the top wedge into a new position in respect to the lower wedge. In this position the distance across the width of the two wedges is reduced allowing the cutter shaft to drop a short distance and lower the cutter away from the locking face. The cutter can then be unscrewed freely from the shaft. By returning the sleeve to the locked position the cutter shaft is raised to its highest setting ready for use and the spanner can be removed.

The chucks are made with eight taper shank sizes covering from 4 MTS to 50 INT to suit cutters with ⅜in , ½in and 1in Whitworth screwed bores.

[Reply Card No. E7142]

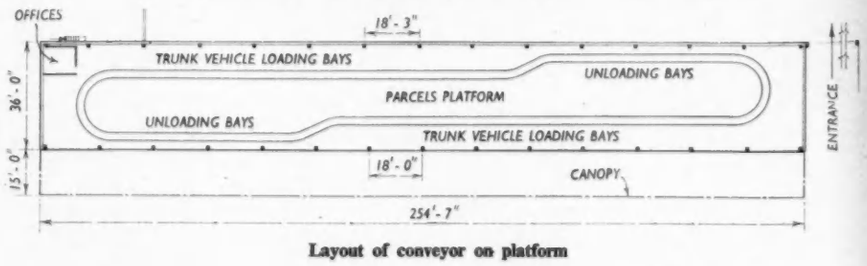
Parcels Depot Conveyor System

A NEW platform equipped with a continuous carousel conveyor, which has been installed at the British Road Services' parcels depot at Coppetts Road in North London, has stepped up the depot's parcels handling capacity by some 30 per cent.

At present about 18,000 packages pass over the two platforms in the depot each day, and the new bank, 250ft long and 36ft wide, is on the trunk dispatch section which loads vehicles serving thirty routes. Its layout can be seen in the photograph we reproduce.

The whole scheme hinges on the conveyor's ability to move packages of a variety of shapes round corners as easily as it moves them in a straight line. There are, as shown in the diagram, fourteen unloading bays, seven on each side of the platform. The conveyor is set to within 3ft of the edge of the platform, keeping to a minimum the expenditure of time or energy when vehicles are being unloaded. Even loading of parcels on the belt is maintained by keeping the two rows of unloading spaces as far apart as possible. On the loading bays for the trunk vehicles a 9ft space between the belt and the edge of the platform gives the sorters

New platform with a parcels conveyor at a British Road Services depot



Layout of conveyor on platform

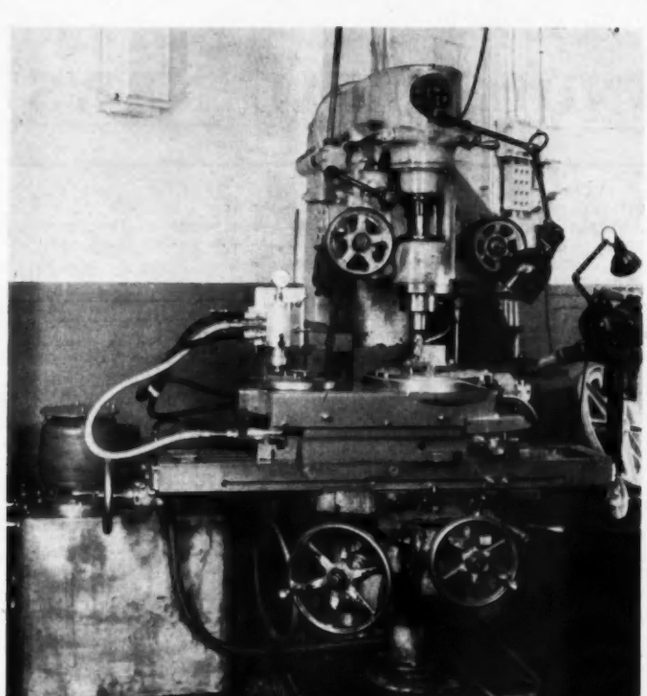
room to allow labelling or temporary stacking when necessary, as the packages are taken from the moving belt.

The installation was carried out by E. H. Burgess, Ltd., under the direction of British Road Services Surveying and Architectural Department.

The conveyor was installed by the manufacturers, Sovex, Ltd., of Erith, Kent. It incorporates a series of specially shaped slats mounted on an endless chain to form a moving track. The chain is below the floor level, so that the moving track runs flush with the surface of the platform. The conveyor is 2ft 6in wide and the overall length of the circuit is 430ft. The conveyor runs at a speed of 105ft a minute and is designed for a superficial load of 40 lb per foot run, the maximum weight of any item being limited to 5 cwt. The slats have interlinking convex leading edges and concave trailing edges so that there is no substantial increase in the ¼in gap between them when the direction changes. Each slat is supported on carbon steel wheels fitted with lubricated and sealed ball bearings. In the main chain each link is separately adjustable, so that normal wear can be taken up without the necessity of moving any part of the conveyor as a whole.

Drive is transmitted by a caterpillar chain from a continuously rated 15 h.p. motor. The direct-on, push-button, automatic starter with no-volt and overload protection is suitable for remote control. A time delay relay is incorporated so that when the "start" button is operated a warning light shows for about ten seconds before the conveyor starts. A separate inching button and reversing switch are provided for maintenance, together with eight emergency stop push-buttons.

[Reply Card No. E7143]



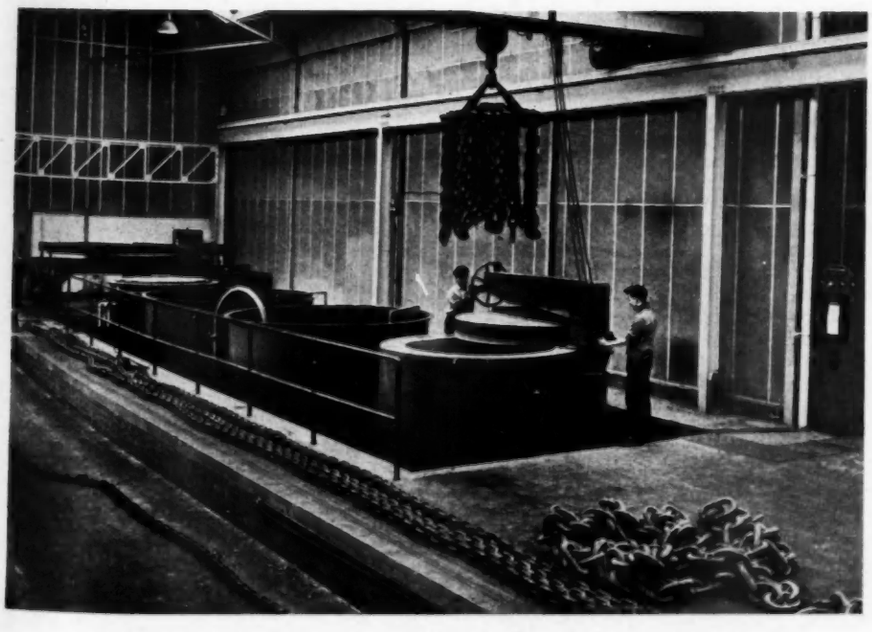
Transferable hydraulic copying attachment for milling machine

Heat Treatment Plant for Chains

OUR illustration shows a new hardening, tempering and normalising plant for chain which has been installed at the works of the British Steel Chain Company, Ltd., Old Hill, Staffs. It includes a pit type hardening and normalising furnace supplied by the Incandescent Heat Company, Ltd., Smethwick, Birmingham, which is arranged for town gas firing. Specially designed radiant bowl burners are used in this furnace and it is suitable for operating within the temperature range 700 deg. to 950 deg. Cent. The arrangement of burners and their design ensures uniform temperature conditions through the heating chamber, high rate of heat transfer to the stock and maximum thermal efficiency of the furnace.

The effective working dimensions of the furnace are 7ft deep by 5ft diameter, enabling it to deal with chains having a maximum length of 90ft with links 2in thick and having an approximate weight of 25 cwts. The furnace combustion system is divided into two zones, each zone being equipped with automatic temperature controlling and recording equipment. A cover, carried on a fabricated mild steel frame equipped with bogie wheels, is raised from the sand seal by four hydraulic jacks. Traverse of this lid and supporting frame is effected by hand wheel.

The furnace chamber is lined with high temperature insulation refractories backed by high grade solid insulation, the complete brickwork structure being encased in a circular casing, reinforced by rolled steel sections. Chains for treatment are carried on a specially designed jig and support stand.



Hardening, tempering and annealing plant for chains 2in thick and up to 90ft long

Tempering of the chains is carried out in an electrically heated vertical air circulation furnace of similar dimensions which was supplied by Metalectric Furnaces, Ltd., Smethwick, Birmingham. This furnace is equipped with a swing lid and a simple geared lifting device. It is designed for operating at temperatures up to 750 deg. Cent. and its applied electrical rating is 222kW. The plant has oil and water quench tanks provided with recirculation and cooling devices situated between the two furnaces.

[Reply Card No. E7151]

Hydraulic Copying Attachment

A HYDRAULIC copying attachment which can be fitted on the table of any standard vertical milling machine or slotting machine is now made by Vero Precision Engineering, Ltd., South Mills Road, Regent's Park, Southampton. This attachment is shown in operation in the accompanying illustration. It is fitted with a 13in diameter work-table and the maximum external profile attainable is 15in diameter.

The top slide of the attachment, which slides in bearings on the cast base, carries twin rotating tables—a 10in diameter template table and the 13in diameter work table which are driven in unison through worm gearing. The top slide is moved longitudinally in respect to the base by a hydraulic cylinder which is controlled through a valve mounted on an overarm attached to the base casting. A stylus at the bottom of this valve actuates the valve spool when it is moved sideways in any direction or vertically by the template profile as the tables rotate. It is stated that an overall copying accuracy to within 0·0005in of the template can be achieved with the attachment. Selection of cutting speed from 2 to 10in per minute is controlled by the machine operator and compensation for variations in cutting radius is automatically controlled.

The hydraulic power pack designed for use with the attachment is fitted with a 1¼ h.p. motor-driven-pump which delivers fluid at up to 5 g.p.m. to the working pressure of 250–300 lb per square inch in the copying system. The attachment can easily be transferred between machines and the power pack is mounted on a castor trolley. A roller bed frame which can be attached to the top of the trolley is used to carry the attachment for its transfer between machines.

[Reply Card No. E7152]

INDUSTRIAL NEWS

Shipbuilding Statistics

Orders amounting to sixty-one ships of 131,000 tons gross are stated, by the Shipbuilding Conference, to have been placed with British shipbuilders during the first quarter of 1961 compared with fifty-three ships of 196,000 tons gross ordered during the same period in 1960. In the twelve months ended March, 1961, orders were received for 256 ships of 562,000 tons gross, the comparative figure for the previous twelve months being 198 ships of 460,000 tons gross. At March 31, 1961, the industry's order book stood at 430 ships, of 3,080,000 tons at a current estimated value of £460 million. Of this total fifty-two ships of 551,000 tons gross valued at £75,000,000 are for export. During the quarter sixty-five ships of 340,000 tons were launched and fifty-eight ships of 296,000 tons were commenced, while sixty-seven ships of 381,000 tons were completed. Of the total contracts just over 1,500,000 tons gross have yet to be laid down, but this includes some tonnage which will not be started on slip until there is an improvement in trading conditions.

Anglo-Soviet Trade

In his presidential address to the forty-fifth annual general meeting of The Russo-British Chamber of Commerce, Sir Greville S. Maginness said that the overall figure for Anglo-Soviet trade in 1960 was £128 million. The export of machinery from the United Kingdom to Russia had maintained its rapid rate of increase, he said, and had been valued at £18,400,000 (excluding electrical machinery) compared with £10,600,000 for 1959. Chemicals shared second place with iron and steel, the president said, both being valued at slightly under £6,000,000, and both showing a substantial increase over the figures for 1959. Re-exports from the United Kingdom, consisting almost entirely of rubber, were more than doubled, and amounted to £16,100,000 in 1960 compared with £7,400,000 for 1959.

Out of a total of £74,900,000 for imports from the U.S.S.R. wood and manufactures thereof made their usual spectacular appearance at the head of the list, the president said, with a total of £33,000,000, an increase of approximately £5,000,000 over the figure for 1959.

Engineering Course for Technicians

In a memorandum to local education authorities, the Ministry of Education has announced details of a new general engineering course for young school-leavers which is to be introduced into technical colleges in the autumn. The one- or two-year course is intended for boys and girls aged fifteen and sixteen who show promise of being able to qualify as technicians. The technical subjects in the syllabus will require about 240 hours a year, and provision has also been made for the inclusion of English and general studies. The scheme provides a common introduction to courses in both mechanical and electrical engineering. Boys who succeed will proceed either to an Ordinary National Certificate course or to one of the various courses for engineering technicians.

This is the first of the general courses foreshadowed in the recent White Paper "Better Opportunities in Technical Education," the Ministry says, as one of several measures intended to increase the supply of qualified technicians to meet the present urgent needs of industry. It has been prepared by the Standing Committee of Technical Examining Bodies in consultation with the professional engineering institutions.

"Payroll Tax" and Industrial Training

The Industrial Training Council has sent a letter to the Chancellor of the Exchequer and the Minister of Labour informing them of the views of the Council on the possible effect that a "payroll tax" might have on the expansion of arrangements for industrial training.

The Council points out in the letter, that it had been working to ensure that so far as possible industry would take advantage of the opportunity presented by the "bulge" in school-leavers over the next few years to make good the present shortage of skilled manpower and at the same time fulfil the nation's social obligations towards these young people. The Council has been urging employers to take on additional young people for training for skilled occupations during the next few years, but it considers that if the proposed surcharge on employers of up to four shillings a week for each employee were to be applied in respect of apprentices and other young persons undergoing systematic training, this might affect the willingness of employers to expand training arrangements for them, and do much to undermine the Council's work. In the event of the tax being introduced, the Council says, there should be a specific exemption in respect of young persons undergoing a course of systematic training.

Shipbuilding Prospects

The report of the sub-committee of the Shipbuilding Advisory Committee, which was established on May 5, 1960, to review the prospects of, and the problems facing, the shipbuilding and ship-repairing industry, has now been published.

The sub-committee recommends that the Government should give the industry's need for credits the most sympathetic and urgent consideration. Managements and trade union leaders, it says, should make the most strenuous efforts to improve their labour relations. Trade union leaders should continue to take the necessary steps to advise their members of the serious prospects facing the industry and the need for the maximum possible co-operation between management and workpeople to achieve the most efficient methods of production ; and employers and trade unions should together review their arrangements for avoiding and settling disputes. Joint yard consultative committees should be set up, the report says, for free consultation about ways and means of improving efficiency as well as welfare matters. Employers and trade unions should constitute themselves as a national joint consultative committee to deal with matters of national interest relating to ways and means of improving efficiency, the report states, and this committee should meet as and when required and should be responsible for keeping alive at all levels the spirit of co-operation. Managements should bear in mind the possible advantages of amalgamations, the sub-committee says, and should, whenever practicable, co-operate to share effort and the use of expensive equipment. The sub-committee also recommends that the Government should consider in the course of its examination of the survey report of the General Council of British Shipping the possibilities of subsidising the scrapping of ships or a scrap and build scheme. The final recommendation in the report states that the Government should review its planned requirements for Government-owned ships, with a view to placing as many orders as possible in the next two or three years.

Industrial Relations in the Motor Industry

The Minister of Labour, Mr. John Hare, presided at a further joint meeting of the leaders of the motor industry and the Confederation of Shipbuilding and Engineering Unions at the Ministry of Labour on April 19. The meeting completed its consideration of the industrial relations problems in the industry, and agreed on a statement of purpose and proposals for action.

A major improvement in relations would result from reducing causes of friction on the shop floor, the statement says, and it was agreed therefore that the employers will review their arrangements for the selection and training of supervisors, including potential supervisors, and similarly the unions will, in accordance with their constitutions, review their arrangements for the qualifications and training of shop stewards, and will give consideration to proposals which the employers have offered for such training to be given under independent auspices such as technical colleges or extra-mural departments of universities. The employers have offered to release shop stewards, with appropriate pay, to take such approved training courses.

The meeting considered that the full-time trade union officials and company representatives should be adequate in number, quality and training to cope with problems as they arose and that they should be empowered either to bring the matter to an agreed conclusion, or if the matter raised issues wider than could be settled at their level to pass it to the next stage of negotiation. The meeting also attached great importance to the problem of communications, and both sides agreed to give consideration to the improvement of their methods of communication. The meeting considered that lack of information about the factors that had influenced the intentions or the actions of the other side was sometimes a cause of difficulty, and added that it was incumbent upon both parties to consult in good faith and to give full weight to the views expressed with a due sense of responsibility. It was proposed that the methods of joint consultation should be examined with this in view.

PERSONAL AND BUSINESS

Appointments

MR. JOHN H. LORD has joined the board of directors of Whessoe, Ltd.

MR. D. J. COLE has been appointed to the board of directors of E. K. Cole, Ltd.

MR. MARK SEYMOUR has been appointed parts manager of J. I. Case Company, Ltd.

MR. PAUL GOTLEY has joined the board of directors of Electrical Remote Control Company, Ltd.

MR. WILLIAM PARKINSON has joined Precision Gear Machines and Tools, Ltd., as chief engineer.

MR. G. C. RICHARDSON has been appointed export manager, overseas division, the British Oxygen Company, Ltd.

DR. T. U. MATTHEW, M.I.Mech.E., has been appointed director manufacturing, Massey-Ferguson (United Kingdom), Ltd.

MR. BRIAN M. LEE, manager of the industrial division of Belling and Lee, Ltd., has been appointed to the board of executive directors.

THE INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND states that Mr. I. M. Stewart has been elected President for the session 1961–62.

BRITISH RAILWAYS, LONDON MIDLAND REGION, states that Mr. M. Harbottle has been appointed civil engineers' new works officer, London.

MR. G. G. THOMPSON has been appointed a director of the Birmingham Chemical Company, Ltd., Lichfield, a member of the Staveley Group of Companies.

SHEEPBRIDGE EQUIPMENT, Ltd., a member company of the Sheepbridge Engineering Group, has appointed Mr. C. E. Hutchinson, A.M.I.Mech.E., as general sales manager.

WALLER ENGINEERING, Ltd., has appointed Mr. B. J. Redman as works manager of the new plant which is due to open in May on the Millbrook Trading Estate, Southampton.

MR. N. M. MISKIN has been appointed as legal adviser to the British Electrical and Allied Manufacturers' Association in succession to Mr. K. F. A. Johnston. He will take up his appointment on May 1.

THE GENERAL ELECTRIC COMPANY, Ltd., announces that The Rt. Hon. Sir Toby Low has been elected vice-chairman of the Company. The Rt. Hon. Lord Coleraine, Mr. M. Sobell and Mr. A. Weinstock have been elected directors.

THE MINISTRY OF HOUSING AND LOCAL GOVERNMENT has announced that on the retirement of Mr. S. L. G. Beaufoy, F.R.I.B.A., from his post as chief housing and planning inspector on July 28, Mr. L. P. Ellicott, A.R.I.B.A., will be appointed to succeed him.

THOR TOOLS, Ltd., formerly Armstrong Whitworth (Pneumatic Tools), Ltd., announces the appointment of Mr. Clarence B. Bergren as managing director. He succeeds Mr. Robert G. Faverty who is returning to the U.S.A. as vice-president of the parent company.

THE COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH and the FIRE OFFICERS' COMMITTEE have approved the appointment of Professor F. H. Garner, F.R.I.C., M.I.Mech.E., as chairman of the Fire Research Board for the next five years. He succeeds Professor A. R. J. P. Ubbelohde, F.R.I.C.

MR. J. BELL, formerly a deputy director and manager of the research laboratories of The General Electric Company, Ltd., has been appointed managing director of the M-O Valve Company, Ltd., a subsidiary of The General Electric Company, Ltd. following the retirement of Mr. G. A. Marriott.

MR. H. G. HINCKLEY has been appointed manager of the machine tool control department of Ferranti, Ltd., Edinburgh. He replaces Mr. D. T. N. Williamson, manager of the department since its inception in 1952, who has left to become director of research and development at Molins Machine Company, Ltd., in London.

THE UNITED KINGDOM ATOMIC ENERGY AUTHORITY states that consequent upon the appointment of Dr. R. Spence as deputy director of the Atomic Energy Research Establishment, Harwell, Dr. W. Wild has been appointed head of the chemistry division. Mr. A. A. Smales, head of the analytical chemistry branch, has been given the status of a division head and will be directly responsible to the Director, A.E.R.E., for the scientific work under his control.

MR. JAMES CARTER, who has served K.L.G. Sparking Plugs, Ltd., in various capacities for twenty-eight years, has now been appointed technical sales representative with K.L.G. special products division.

METROPOLITAN-CAMMELL CARRIAGE AND WAGON COMPANY, Ltd., announces with regret the resignation of Mr. H. N. Edwards as chairman of the company. He has been succeeded as chairman by Sir Ralf B. Emerson, M.I.C.E., M.Inst.T. At the same time, Sir James Reid Young, will retire from the board and will be replaced by Mr. A. M. Hird, M.I.Mech.E. Mr. Edwards, who has been with the company or its predecessors for fifty-one years, will continue as a director.

Business Announcements

F. PERKINS, Ltd., Peterborough, states that a new company has been formed in Italy. The headquarters of the new company, Perkins S.p.A., is in Como.

FENTON BYRN AND CO., Ltd., which specialises in the design and manufacture of fans, ventilating and heating appliances, has opened a new factory at West Molesey, Surrey.

THE INSTITUTE OF ADVANCED MOTORISTS, Ltd., states that with effect from May 1 its address will be Empire House, Chiswick High Road, London, W.4 (telephone, Chiswick 4403).

BAKER PERKINS, Ltd., MITCHELL ENGINEERING, Ltd., and MITCHELL CONSTRUCTION COMPANY, Ltd., have formed a new company, Peterborough and Spalding Aviation, Ltd., to operate their executive aircraft from Westwood Airfield, a former R.A.F. airfield.

THE SHIPBUILDING CONFERENCE, THE SHIPBUILDING EMPLOYERS' FEDERATION, the DRY DOCK OWNERS' AND REPAIRERS' CENTRAL COUNCIL, and the NATIONAL ASSOCIATION OF MARINE ENGINE BUILDERS, 21, Grosvenor Place, London, S.W1, state that their telephone number has been changed to Belgravia 5131/5.

THE COMPOFLEX GROUP has opened a warehouse, stocking both flexible and rigid tubing, at 9–11, Bordesley Green Road, Birmingham, 9 (telephone, Victoria 0407-8). The warehouse is under the control of Mr. J. C. Franks, the Midlands area manager, with Mr. J. Reynolds in charge of the rigid tubing business.

THE SOUTH OF SCOTLAND ELECTRICITY BOARD has appointed Messrs. Kennedy and Donkin to be consulting engineers for its £50,000,000 Lothians power station which will have a capacity of 1200MW. Messrs. Kennedy and Donkin will be assisted by Messrs. James Williamson and Partners and Messrs. Strain and Robertson.

LEE, HOWL AND CO., Ltd., Tipton, Staffs, has concluded an agreement with the Webster Electric Company, Racine, Wisconsin, U.S.A., to manufacture the range of Webster oil burner fuel units, models 1R and 2R, for sale in the United Kingdom, Eire, Denmark, Sweden, Norway, South Africa, Australia, and New Zealand.

MOXEY, Ltd., Birmingham Road, West Bromwich, Staffs, has concluded an agreement with Laeis-Werke, Trier, Germany, to co-operate in the building of plant for the production of dolomite bricks for lining oxygen-blown steelmaking furnaces. Contracts for such plants have been placed recently by Richard Thomas and Baldwins, Ltd., and the Consett Iron Company, Ltd.

OWEN-KLEINE STRUCTURES, Ltd., P.O. Box 10, Darlaston, Wednesbury, Staffs, a new member of the Owen Organisation, has been formed by Rubery, Owen and Co., Ltd. (Structural Division), and Kleine Reinforced Concrete, Ltd. The resources of the two companies have been combined to develop a system of lift slab construction applicable to multi-storey buildings.

IMPERIAL CHEMICAL INDUSTRIES, Ltd., Imperial Chemical House, Millbank, London, S.W.1, states that an arrangement has been made between Head Wrightson Processes, Ltd., and the "Alfloc" Water Treatment Service of Imperial Chemical Industries, Ltd., whereby the two concerns will collaborate in the assessment and solution of problems relating to treatment of trade and other wastes before discharge to sewers or water courses. In addition, a special study will be made of the re-use of water within industry with the view to alleviating problems of water supply and of disposal of wastes.

BAKER PERKINS, Ltd., Westwood Works, Peterborough, announces that an agreement has been signed for the acquisition of James Halley and Sons, Ltd., West Bromwich. Mr. Angus M. Halley remains as managing director of James Halley and Sons, Ltd., which will continue to operate as a separate company. All executive directors retain their appointments and will be joined by Mr. L. P. Simpson and Mr. P. Marlow, directors of Baker Perkins, Ltd., and Baker Perkins (Exports), Ltd., respectively and Mr. R. H. Wilkins, a joint managing director of Baker Perkins, Ltd., who has been appointed chairman.

THE ELECTRICAL RESEARCH ASSOCIATION announces the composition of Divisional Committee No. 1—Insulating Materials. Dr. L. G. Brazier, chairman (British Insulated Callender's Cables, Ltd.); Mr. R. F. Archer (Micanite and Insulators Company, Ltd.); Dr. J. S. Forrest (Central Electricity Generating Board); Mr. V. J. Francis (The General Electric Company, Ltd.); Mr. J. D. Nicholson (Yorkshire Electricity Board); Mr. M. E. Peplow (Central Electricity Generating Board); Mr. W. Reddish (Imperial Chemical Industries, Ltd.); Mr. E. H. Reynolds (British Insulated Callender's Cables, Ltd.); Mr. T. R. Scott (Standard Telecommunications Labs., Ltd.); Mr. H. Willott Taylor (Southern Electricity Board); Mr. G. H. Thornley (Castrol Industrial, Ltd.); Mr. L. H. Welch (London Electricity Board). Dr. H. G. Taylor, director of the Electrical Research Association, is an *ex officio* member of the Committee, and the secretary is Mr. G. A. W. Taylor of the Electrical Research Association.

Contracts

BRAITHWAITE AND CO., STRUCTURAL, Ltd., has been awarded a contract by English Steel Rolling Mills Corporation, Ltd., to supply and erect 3000 tons of structural steelwork at the Corporation's new bar mill at Tinsley Park, Sheffield.

LITHGOWS, Ltd., has received an order from The Currie Line, Ltd., for a cargo liner of 13,100 tons deadweight on closed shelter deck draught and 11,300 tons deadweight over an open shelter decker. J. G. Kincaid and Co., Ltd., will supply the main machinery, consisting of a Burmeister and Wain turbo-charged poppet valve engine having eight cylinders of 620mm bore by 1400mm stroke, and developing 8500 b.h.p. in service to give a service speed of 16 knots.

THE MITCHELL CONSTRUCTION COMPANY has been awarded the first civil engineering contract for the construction of the Central Electricity Generating Board's West Burton Power Station in Nottinghamshire. The contract is valued in the region of £1,300,000 and covers all the preliminary civil engineering work; 1,700,000 cubic yards of excavation, access roads and rail track, main drainage, flood protection and other miscellaneous work. The consulting engineers are Messrs. Merz and McLellan.

THE BRIGHTSIDE FOUNDRY AND ENGINEERING COMPANY, Ltd., has received an order worth more than £300,000 for a new 14in merchant bar and section mill for the Wolverhampton works of the Wolverhampton and Birchley Rolling Mills, Ltd., a member of the Thomas W. Ward Group. The structural steel department of the parent company will erect the buildings for the new mill, and the overhead electric cranes will be supplied by John Smith (Keighley), Ltd., another Ward Group member. When the new mill is complete, in two to 2½ years, the productive capacity of the Wolverhampton company will be increased to about 150,000 tons of steel bars and sections a year.

Miscellanea

RUSSIAN CASTINGS PRODUCTION.—As part of its service to the foundry industry, the British Cast Iron Research Association has undertaken the publication of a complete cover-to-cover translation of the monthly Russian foundry journal, *Liteinoe Proizvodstvo*. It will appear under the title *Russian Castings Production* and will form part of the programme of Russian translations sponsored by the Department of Scientific and Industrial Research. Subscription rates for twelve issues are £10 10s. 0d. in this country and 35 dollars or £12 10s. 0d. outside the United Kingdom, whilst single copies may be purchased at £1 10s. 0d. or £1 15s. 0d. respectively. All inquiries and orders should be addressed to the Publications Officer, British Cast Iron Research Association, Bordesley Hall, Alvechurch, Birmingham, England.

CONTINENTAL AFFAIRS

by Our Continental Editor

Traffic Improvements in Vienna

ABOUT a year ago, work began on three major installations designed to relieve traffic congestion on Vienna's Ringstrasse, the well-known boulevard encircling the city centre. This ring road forms one of the principal connections in the city and is used by motor traffic as well as by a large number of tram lines which radiate from it into the suburbs at various points or have their central terminals there. In order to remove at least some of the encumbrance of pedestrians crossing at street level, two pedestrian subways are being installed at the junctions of Bellaria and Babenbergerstrasse. These will have three and four staircases respectively, each with one fixed stair and one escalator. In the morning and evening rush hour, the subways will be used by 4000 to 6000 pedestrians and, in addition, by large numbers of passengers changing trams. Public conveniences will be installed and the passages will be embellished with showcases. The adits will be protected by the same cantilever roofs as the tram stops. The cost of the two subways amounts to 12,000,000 and 15,000,000 Austrian schillings.

Much more comprehensive are the measures which are being taken at the Schottentor, a fivefold junction where a main road from the city centre crosses the Ringstrasse and divides into two radial roads leading into the suburbs, the Universitätsstrasse and Währingerstrasse. In addition to trams passing along the Ringstrasse several radial lines terminate there. The turnround loops of these trams used to cross the main traffic streams and thereby constituted a major obstacle. A far-reaching solution is being adopted here at an estimated cost of 56,000,000 Austrian schillings.

Much of the cost of the scheme is due to the fact that it was necessary in order to maintain tram traffic to construct 1300m of temporary bridges and track diversions. Part of the Schottentor foundations, moreover, lie in the region of former fortifications and had to be carried down to 14m below street level. In all three cases the resiting of sewers and services formed a major item on which work had already been started in 1959.

At the Schottentor (Figs. 1 and 2) it was necessary to resite 3700m of water mains, over 600m of gas mains, 26km of power cables and 32km of post office cables. The terminal tram loop for trams using the Währingerstrasse, the more easterly of the two suburban roads, is being sited in a large excavation which will be accessible over ramps. This excavation will be roofed over at the periphery, leaving the centre open so as to provide daylight and ventilation for the underground tram stop. The terminal loop serving the other suburban road will be on top of the concrete roof at street level.

About 36,000 square metres of roadway and 12,000 square metres of pavements have to be rebuilt or newly constructed. Westbound tram-

Fig. 2—The Schottentor site seen towards the suburbs (July, 1960). In the background, the Votive church

Fig. 1—Tram terminal at Schottentor under construction (view towards city centre, August, 1960). Trams along the Ringstrasse boulevard are being diverted over a temporary bridge

stops in the area are being combined with the tram terminals into two stops, one on the surface, the other below road level. The surface stop will be protected from the weather by a roof. The underground stop will have six adits of which five will be equipped with an " up " and a " down " escalator each, as well as a fixed flight of stairs, while the sixth adit will have only a fixed flight of stairs. These adits will serve not only tram passengers but will allow pedestrians to cross below street level. Installations will include dayrooms for tram crews, a control room and electric substation, heating and ventilating plant, public conveniences, and coin box telephones both at street level and under ground, Improvements to motor traffic will involve the widening of the Universitätsstrasse to carry two carriageways, of 6·5m and 9m width, and of the Währingerstrasse to carry two carriageways each 10·5m wide. It is proposed to complete the work by the summer. In addition to the Schottentor reconstruction proper, the opportunity is being taken to instal an underground garage in the area of the public gardens situated in the triangle between the two suburban roads and the Votive church. This garage is being built by the cut-and-cover method, and will have space on two levels for 600 cars. On completion of the work the park will be restored.

The total area of the garage site extends approximately over a rectangle 137m by 83m

under the Votive Park and partly under the adjoining streets and amounts to 11,000 square metres. The garage is connected by a passage with the tram terminal. It is a reinforced concrete structure with a troughed roof resting on columns. A certain number of the troughs are used as ventilation ducts for which purpose they are covered. The whole of the roof, excepting the road areas, will be under an earth cover approximately 0·8m thick. Some of the troughs not used as ducts will provide a greater depth of soil suitable for the planting of trees. Access and exit are over ramps, with staircases for pedestrians. Incoming vehicles pass automatic entrance gates on the upper level whence they reach the parking places for 235 cars, the washing and service station, and the ramp leading to the lower floor on which there is room for 340 cars. Leaving cars pass cashiers' kiosks on their way to the exit ramp. Heating and ventilation of both storeys are to be centralised, and ducts are being provided for this purpose along the external walls, in the floor, and in the roof. The boiler house is sited away from the garage and will be connected with the ventilation machine hall by pipes. During power cuts the garage will be able to obtain its current from an emergency generating set.

Hot Ingot Milling Machine

WITH the increasing demand for higher quality steel, the question of the economic conditioning of ingots has become of prime importance. It is not feasible to produce ingots entirely and consistently free from superficial defects such as cracks, cold laps, inclusions and various oxides and impurities. Previously, it was sufficient to remove the more obvious defects with hammer and chisel. Later on much more thorough-going methods came to be employed such as pneumatic chisels, swing grinders, and square-turning lathes. All these could only be applied to cold ingots. Moreover, certain special steels were adversely affected by the cold working involved, so that costly heat treatments became necessary. Nowadays, oxygen scarfing is the method of choice, iron powder being added to the flame in the case of alloy steels. This gives a good average product at relatively low cost. Its disadvantages may be considered to lie in the limited accuracy of the process if carried out by hand, and the high cost of mechanising it, which renders mechanisation uneconomical except for large quantity production in continuous mills. In addition, large amounts of oxygen are required, and efficient extraction of the fumes has to be provided.

With the " hot peeling " method developed by Innocenti, of Milan, a convenient and effective process is claimed to have been evolved in which the ingot is treated as it comes from the soaking pit at a temperature of 1200 deg. Cent. All ingot faces are " peeled " in succession to an adjustable depth. Since the ingot is not cooled after stripping, the danger of splits or cracks is completely avoided.

The machine used is shown in Fig. 1. It is in effect a milling machine of special design, comprising an ingot feed roller table, carriage movable on the machine bed, ingot loading and tilting device, cutter head, and arrangements for the discharge and collection of chips.

The roller table brings the ingot to the loading and tilting device and resembles the table of a blooming mill.

Made of a solid steel casting, the movable carriage slides on its adjustable bronze pads on a single-block cast iron bed fitted with exchangeable guideways. The carriage frame forms a cavity open on one side, into which protrude from the bottom two adjustable anvils faced by downstroking hydraulic clamping cylinders. Between these the ingot is held, after adjustments have been made by means of the two horizontal positioning cylinders. Another oil-hydraulic cylinder traverses the carriage. All the oil cylinders, circuits, drive mechanisms, and clamping jaws, are water-cooled. Telescopic shields prevent chips falling on the guideways.

The loading and tilting device places the ingot into the carriage, tilts it after each pass, and finally returns it to the roller table. It consists of a base on which moves a wheeled carriage fitted with a hydraulically jacked table on which the ingot is placed. Two arms are hinged at one of their ends on this table, while the other end rests on fixed, upward curving guides on the main carriage. As the table moves inwards, these arms ride up on the guides and tilt the ingot. A vertical plate on the loading device, against which the ingot is located by the horizontal cylinders on the carriage fixes its position in relation to the cutter head, and thus establishes the cutting depth.

The vertical headstock spindle is driven by a motor through a reduction gearbox. The cutter (Fig. 2) which in some versions has a diameter of 1·5m, in others one of 2m, is keyed to the spindle, with provision for hydraulic locking and unclamping by means of a central cylinder in the spindle. The cutter is in two parts: a cylindrical one for the straight sloping blades which machine the ingot faces, and a short ring for the moulded cutters for the ingot chamfer. The blades are held by wedges, and are usually made of plain carbon steel, heat treated to bring them to a strength of 100 kg per square millimetre. They can easily be produced and resharpened by flame cutting or copy-milling. Blades of special steel are, however, considered to give superior results. As interchange of the cutter heads and re-sharpening of blades is so easy, it is possible to operate the machine continuously with only two milling cutters.

Fig. 2—Cutters have a diameter of up to 2000mm. Two sets of blades are fitted, one for the ingot face and one for the chamfer. The cutter body sits on the conical, keyed end of the cutter spindle. It is clamped and released by means of a hydraulic cylinder in the spindle

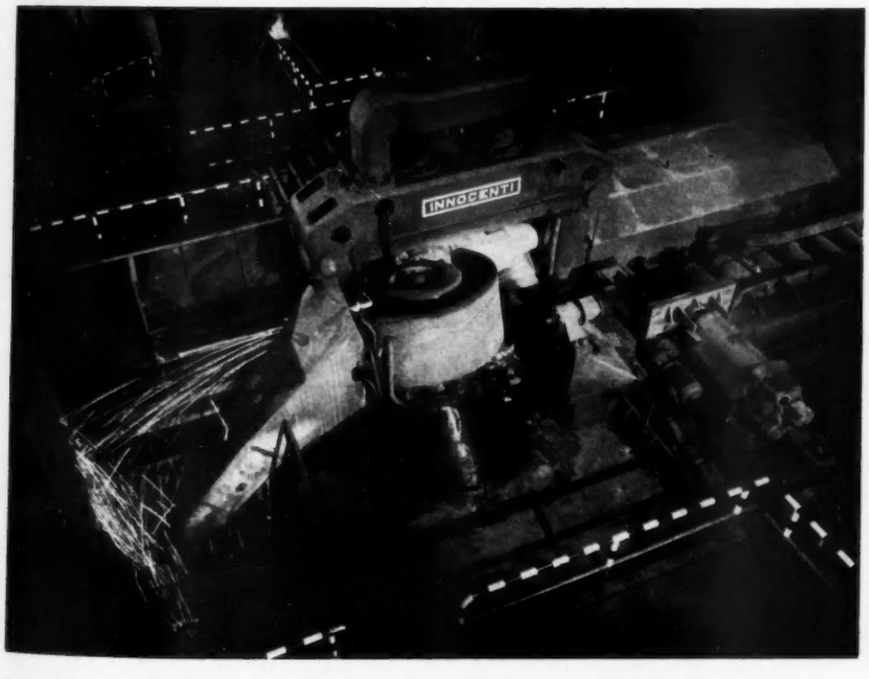


Fig. 1—The ingot from the soaking pit is fed by the roller table (right) to the loading and tilting device (right foreground) which places it into the carriage, and also tilts and replaces it after each pass. Cutting speed is 500 metres per minute, carriage feed rate up to 3 metres per minute

The oil-hydraulic and lubrication units are housed in a pit at the back of the machine, the former incorporating water-cooling in order to prevent excessive fluctuations in oil viscosity. Movement of the power cylinders can be controlled and regulated from the control panel. The ingot loading and tilting device and the extensions of the main carriage cylinders are open-circuit grease lubricated from a central point. The cutter reduction gear is lubricated by a closed oil circuit, while the main carriage sliding surfaces on the base are oil-lubricated by an open circuit, the oil being afterwards collected in drip mouldings, and returned to the tank above where it is filtered before being re-used. Electric interlocks prevent the oil-hydraulic system from being started without the lubricating groups being in operation.

The control panel is housed in an elevated enclosed panoramic cabin near the machine. The electric circuits enable the machine to run on an automatic, semi-automatic, or manual cycle. It is possible to stop the automatic operation at any point and to carry out adjustments manually.

Machines have been designed for ingots of 1300 kg, 3000 kg, and 5000 kg weight, and one

CONTINENTAL AFFAIRS *(continued)*

for 8000 kg ingots is at present under construction. The maximum ingot dimensions of the 5000 kg version are, face width 650mm, and length inclusive of sink head 2200m. The main carriage stroke is 4200mm, and the cutter diameter over blades, 2000mm. A cutting speed of 500m per minute is used, in conjunction with an adjustable feed rate of 1 to 3m per minute. The total installed power is 750kW, of which the cutter motor alone consumes 600kW.

For the peeling process, the ingot which is stripped at approximately 800 deg. Cent. is heated in the soaking pit to 1200 deg. Cent. During peeling the ingot cools by about 100 deg. Cent. which has to be made good before rolling. Compared with conventional conditioning when the ingot has to be allowed to cool to the ambient temperature, there is a considerable saving in time and fuel. Since the hardness of all kinds of steel is similar at 1200 deg. Cent., the process can be applied with equal facility to alloy steels. Weight reduction of the ingot amounts to about 5 per cent, but this loss is stated to be fully recoverable by remelting.

Grain Silo at Frankfurt

A LARGE silo for storing a total of 14,500 tonnes of barley and malt is at present under construction on the Sachsenhäuser Berg, a hill in the southern part of Frankfurt-on-Main. Because the available site was too small for a silo of normal height sufficient to hold the required tonnage, the owner, Henninger-Bräu KG a. A., decided on a skyscraper silo with 65m-high

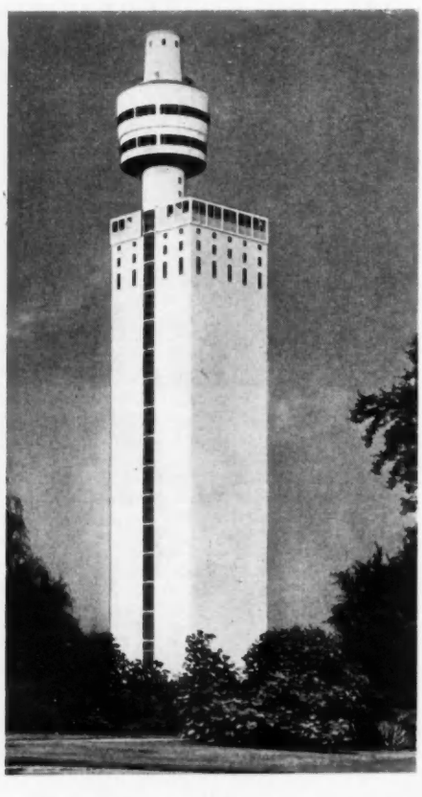


Fig. 1—Grain silo with 14,500 tonnes storage capacity. The silo is surmounted by a roof garden and restaurant tower, the whole standing 118·5m high

compartments (Fig. 1). On top of the 83m-high silo building proper is a roof garden, and a tower with restaurant and observation platforms which rises to a height of 118·5m, and affords visitors a view of the city of Frankfurt and the surrounding countryside. The building measures 20·7m by 2·7m, and rests on rock on a 1·25m thick foundation slab 25m by 25m. Existing vaults situated about 11m below ground level had to be filled with concrete. A 3·5m-high basement houses machinery and stores, while on the 4m-high ground floor there is a restaurant. On the floor above are the discharging facilities for the silo compartments. There are sixteen compartments measuring 4·1m by 4·1m between centres of the 0·18m thick walls. Two cells are three-quarter standard size, five are half-size, and eight one-quarter size. A main staircase of 613 steps leads from the basement up to the tower observation platform. Normally, access is by means of two rapid lifts which can do the journey in just under one minute. One of the half-cells houses the grain elevators. For emergency use there is an escape ladder in steel construction.

Above the silo compartments are two 5m-high distributor storeys containing the equipment for distributing the grain among the various sections. The roof forms a roof garden with flower beds, dance floor and fountains, surrounded by a covered area with tables. The 35m-high cylindrical tower of 7·3m diameter and 0·2m wall thickness toes the front of the silo on which it stands. From this tower three platforms jut out with a maximum diameter of 17m, each supported on twenty cantilever beams. Between them they form two storeys. The lower one houses the restaurant kitchen as well as an assembly room. On the upper storey is a restaurant for 160 persons. It has a revolving floor which turns at the rate of two revolutions per hour, so as to give the guests a complete panoramic view of Frankfurt and its surroundings.

Fig. 2—Some of the thirty-one silo compartments under construction. The 65m-high section was built in one month, using continuously jacked sliding shuttering

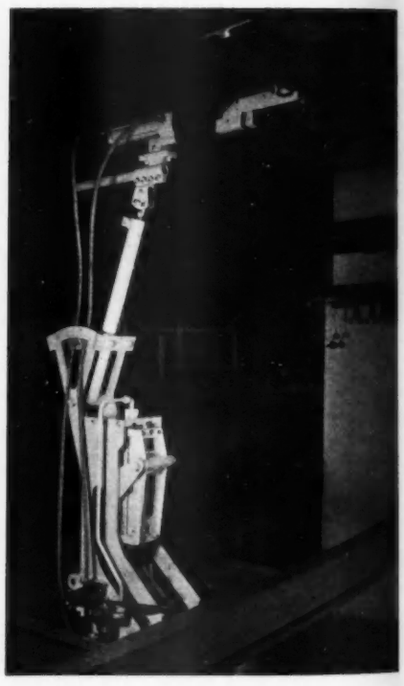
In the top section of the tower is the machinery for the lifts.

Up to the bottom of the silo traditional timber shuttering was employed. The silo compartments themselves were concreted with the help of 1·1m-high sliding shuttering which was continuously raised by means of hydraulic jacks while concrete and reinforcements were being placed all the time in thin layers (Fig. 2). In this work daily progress averaged 2·30m, so that the whole 65m high silo section took about a month to complete. For the top portion, normal timber shuttering was used.

With compartments fully topped up, the pressure on the silo walls can reach 4·5 tonnes per square metre. The total weight of the building and its contents amounts to some 31,000 tonnes, which is transmitted to the base slab by columns measuring 1·1m by 1·1m, each of which carries 1200 tonnes. For the structure alone approximately 6400 cubic metres of concrete and 650 tonnes of reinforcement steel were required. The contractor was Philipp Holzmann Aktiengesellschaft, Frankfurt/Main (architect, Professor Dr.-Ing. Lieser, Darmstadt).

Press Unloading Device

In the accompanying illustration we show a fully automatic mechanical unloading device for presses. This is stated to have the advantage, as compared with manual press operation, of reduced labour costs and greater safety. It is a piece of equipment which is mounted independently of the press. Made in three different sizes



Fully automatic unloading device for presses

or to special requirements by Theodor Gräbener, Werthenbach (Kr. Siegen), German Federal Republic (United Kingdom representation: Press and Shear Machinery Company, Ltd., 172–178, Victoria Road, London, W.3), the device which is pneumatically actuated immediately grips the component as soon as the ram has risen clear, then pulls it out and stacks it or deposits it on a conveyor belt which takes it to the next press in the line.

THE AMERICAN SCENE

By Our American Editor

Transfer Machine for Milling and Boring Small Engine Blocks

A NEW "Transfer-matic" transfer machine which processes cylinder blocks for a European four-cylinder engine, has been designed and built by the Cross Company, of Detroit, Michigan. It is of particular interest because of the integration of all milling and cylinder boring with assembly and the many other operations required to finish the block. Briefly, cast iron blocks, with their tops and bottoms broached, are loaded in section I where heavy metal-removing operations are performed. In section II, ends of the blocks are milled and cam bores are roughed. Following a banking conveyor, the blocks enter section III where their sides are machined. Section IV includes operations for drilling and tapping holes on the top and bottom of the blocks and finish reaming the tappet holes. After they emerge from a washer, the blocks enter section V for bearing-cap assembly. In section VI, the cam and crank bores are machined.

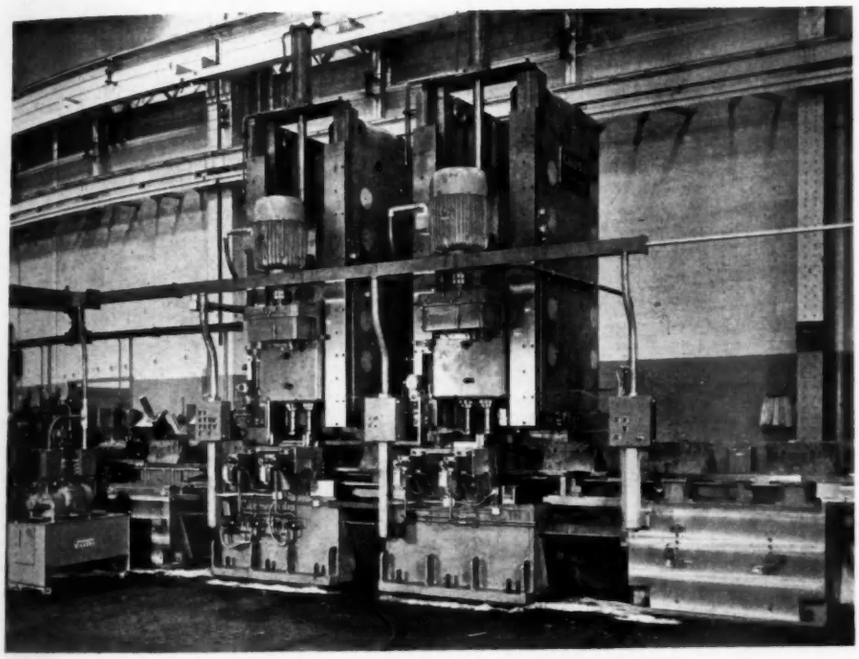


Fig. 1—Twin stations in section I of transfer machine for boring of alternate cylinders

As soon as the blocks are loaded in section I, they are rolled 270 deg. to remove any remaining broaching chips and to position the casting for processing the locating holes. Then, the blocks are clamped and probed. One probe simulates the camshaft boring-bar support and the other checks the block cavity for tappet-hole bushing-plate clearance. The probes are positioned by gravity and air circuits are provided to indicate interference. If there is interference, the block is removed from the line at the next station. The crank bearings of the good castings are straddle-milled in the next working station. In the following two working stations, anchor-lock notches and oil-slinger grooves are milled from one side of the machine, and tappet holes are drilled from the other. Chips are removed between these stations so that the part will be clear to receive the bushing plate. Just prior to cylinder boring, the chips are again removed. Alternate cylinders are bored in pairs in two stations. Individual boring spindles are mounted in cartridges that are housed in water-cooled compartments to maintain constant operating temperature. The slide for each pair of spindles is mounted within a cast column that is fastened on top of the base. Through special design of these units, the centre-lines of the spindles and ways are in the same plane to eliminate forces that would tend to divert the spindles from their true paths.

A simple rotary bar slides the castings through section I with a 36in index. Section II uses a lift-and-carry transfer to clear the boring-bar support in this section. The index units are only 24in because the blocks are mounted crosswise to the line. The advance and return strokes of the transfer bars are powered by the same hydraulic cylinders that return and feed the milling cutters. This is one example of savings that have resulted by including milling of the ends of the blocks in this line. A separate transfer mechanism is not needed.

Two saddles are each equipped with a roughing and a finishing head for one end of the block. They are driven by separate hydraulic cylinders but their motions are mechanically tied together. At the end of a milling feed stroke, the ends of one block have been rough-milled, two rough-milled blocks are in idle stations between the cutting stations, the next block has been finish-milled and the transfer bars have been returned to the "forward transfer" position. The transfer bars are then raised, and the saddles and bars move forward together, advancing all blocks one station and positioning the cutters for the next feed stroke. In addition to obtaining a "free" motion by integrating movements of the milling saddles and the transfer bars, this method results in zero relative motion between cutters and blocks during transfer. Any cutter retracting movements are thus unnecessary because the cutters do not move across machined surfaces.

By the time the blocks have had their ends milled, all heavy metal-removing operations are completed. The later operations are light so that the generation of heat is minimised and internal stresses relax. The blocks have a chance

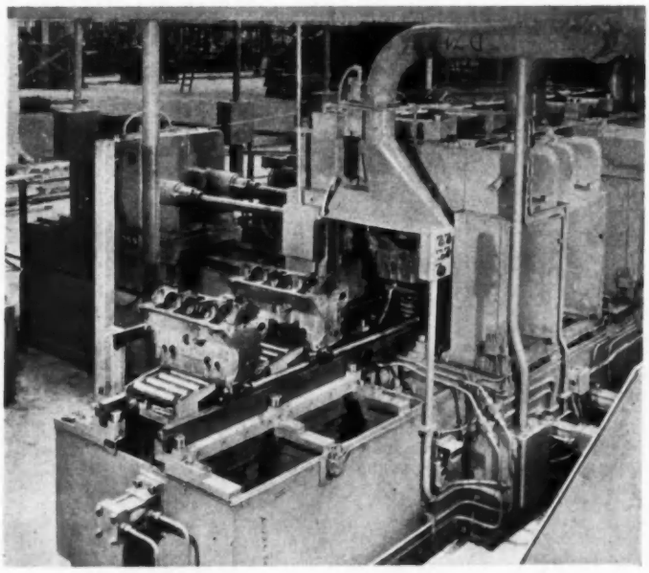


Fig. 2—Engine blocks, with bearing caps assembled, entering the cam and crank boring section

THE AMERICAN SCENE *(Continued)*

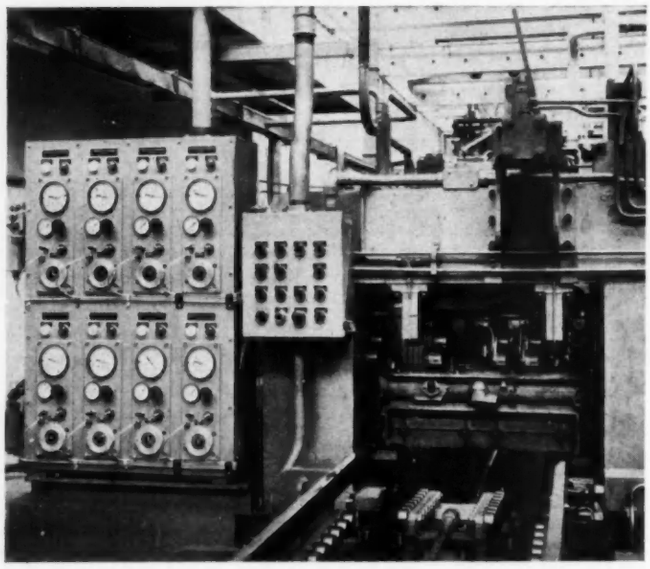


Fig. 3—Air-gauging station for checking each engine block bore individually and simultaneously

to stabilise before the finishing operations are accomplished. In the remainder of section II, the operations are conventional, except for a drilling operation and a porosity check. The drilling of the oil-gallery holes is done, together with other operations, in six different stations. The chips are blown off the blocks, and then the oil-gallery hole is plugged. Air pressure is introduced into the hole. If leakage occurs during the test period, the porous block is sprayed with yellow paint so that it will be removed from the line without wasting additional work on it. The blocks are turned 90 deg. in the horizontal plane in the last station of section II, and are then moved to a long banking conveyor.

The blocks enter section III and are transferred through it by a rotary transfer bar. Since transfer motions are not tied to milling-cutter motions in this section, the milling cutters are retracted as they return to their starting positions. The first machining operations in this section are the milling of pads on both sides of the blocks. There follow a considerable number of conventional drilling operations—seventeen holes are worked on from both sides of the machine in one station. Following blow-off, probing and tapping, the blocks are rolled over and the eight tappet holes are rough reamed. Both ends of the cylinder bores are chamfered in another station.

Following chamfering, the eight tappet holes are semi-finish reamed. Eight stations later they are finish reamed in a station that is effectively isolated from the line. No other operations are accomplished in this station and it has its own filtered coolant system. From section IV, the blocks are pushed onto an accumulating conveyor for delivery to a washer.

After leaving the washer, the blocks go through a banking conveyor and are delivered to section V. In this section, an operator manually places four bearing caps and inserts eight bolts in each block. The bolts are automatically tightened to a pre-set torque in the single working station of this section. The blocks then go onto another accumulating conveyor for delivery to the next section. An automatic loader spaces blocks from the conveyor and loads them two at a time into the first station of section VI. In the first working station (Fig. 2), camshaft and crankshaft holes are bored. These long boring bars are supported by live bushings on the outside of the blocks and by fixed supports within them. In the third station of this section, thrust faces on one of the bearing caps are faced, and the oil-slinger and oil-seal grooves are generated. Finish boring of the camshaft holes and semi-finish boring of the crankshaft holes are performed in the next station. Following automatic cleaning with brushes and air blasts, the blocks go to an air-gauging station (Fig. 3) where all bores are checked.

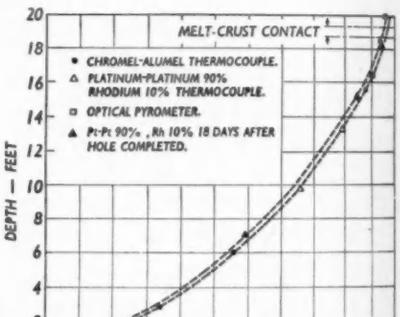
To process these blocks requires the establishment and finishing of 123 assorted holes and several surfaces. The cycle times of the various sections of this transfer machine are different but, through the banking conveyors, the line balances out to a production of about eighty-five blocks per hour. The line maintains high block accuracy, and its design is sufficiently flexible to accommodate changes in the design of the blocks.

Drilling into Molten Lava in Hawaii

The eruption at the Kilauea Iki volcanic crater in Hawaii in November, 1959, produced a lava lake over 300ft deep containing about 45 million cubic yards of lava. An experiment was conducted under the "Plowshare Programme" of the U.S. Atomic Energy Commission to obtain knowledge of the problems encountered when drilling through the crust of the lake into molten rock, and to obtain as much volcanological data as possible. On July 25, 1960, after drilling only 19ft, the crust of the lava lake was pierced, making possible temperature measurements of the molten rock, collection of gas samples emanating from the melt, and direct sampling of molten lava. The experiment clearly demonstrated that it is possible to drill into hard rock at temperatures up to 850 deg. Cent. with standard core-drilling equipment, using compressed air to cool the rock and to remove the cuttings. By using water to cool the rock and drilling with water periodically injected into the compressed air line, it is possible to drill with standard equipment into rock that has been at temperatures exceeding 1050 deg. Cent.

The first 14ft of hole was drilled to 3·5in in diameter and cased to seal off possible communication with the surface. Vibration as a result of air drilling limited the core recovery, and diamond bits were badly damaged by heat and inadequate air circulation; otherwise, drilling proceeded rapidly. The remainder of the hole was left uncased and drilled to a 2in diameter. Drilling progressed more slowly due to the high temperatures encountered and also due to an increase in the rock density. At 15·5ft depth silver solder on the bits melted, and the core recovery was poor. Binding of threads on the drilling tools caused considerable difficulty; however, powdered graphite as a lubricant cured this trouble. At 16·8ft, water was used to cool the hole and was periodically injected into the compressed air line for additional cooling during drilling. This worked very well and the drilling rate increased from 1·5ft in 8 hours to 3·5ft in 3½ hours. Core recovery remained poor, but there was little damage to the drill bit.

The crust-melt boundary was encountered at about 19ft and the melt was quite fluid at 20ft. The air-and-water-vapour drilling coolant quenched a protective crust between the bit and the melt and further drilling did not cut this crust, but pushed it into the melt. At 19·5ft the bit and tools dropped slowly in the hole of their own weight. A core of melt was then taken by cutting off circulation, allowing the silver solder to soften and the teeth on the bit to close inward. Circulation was restored and about 2in of melt was trapped in the bit. Sulphur from the outgassing melt was also deposited on the bit. Gas samples were subsequently collected and it was also found that melt samples could be obtained by attaching a tapered cylinder "shoe" to the drill rods and driving this into the melt by hand. The core of melt thus obtained could then be tapped out of the shoe. At 20·4ft further removal of melt by sampling did not deepen the hole. In less than two days the lava had risen from 20·4ft to 18·7ft deep in the hole. The hole was then sealed with a capped stainless steel pipe. A platinum-platinum 90 per cent rhodium 10 per cent thermocouple package was installed in the pipe to study the cooling history at three points in the lava lake crust. Difficulties were encountered in obtaining temperature data as the hole was drilled. The accompanying graph shows a plot of the most reliable measurements. These measurements



Measured temperature as a function of hole depth

are preliminary and require further evaluation. The peak temperature of 1064 deg. Cent. was obtained with an optical pyrometer and is probably a little low due to some gas in the hole.

It is planned to run complete chemical and petrographic analyses on the core and melt samples. The gas samples will be analysed, O^{16}/O^{18} ratios will be determined on the water and carbon dioxide gases, and the deuterium and tritium content of the water will be measured. These will be compared with local rain and ocean water to determine whether they are primary gases or not. The hydrogen-water ratio of the gases and the FeO/Fe_2O_3 ratio of the melt and crust samples will also be determined. Thermal conductivity will be measured on the crust samples, making possible a calculation of thermal conductivity of the crust material as a function of temperature and a calculation of heat flow through the crust.

This work was conducted as part of the "Plowshare Programme" of the U.S. Atomic Energy Commission, by members of the Lawrence Radiation Laboratory of the University of California at Livermore, California.

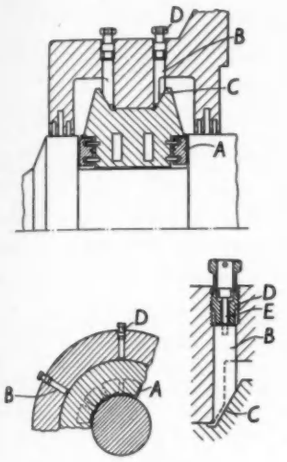
BRITISH PATENT SPECIFICATIONS

The dates printed are those of application and publication on completion. Copies of specifications may be obtained at the Patent Office Sales Branch, Southampton Buildings, Chancery Lane, W.C.2, 3s. 6d. each

BEARINGS

863,299. July 9, 1959.—IMPROVEMENTS IN THRUST BEARINGS, Svenska Turbin Aktiebolaget Ljungstrom, Finspong, Sweden. (*Inventor : Per Bertil Herbert Dahlgren.*)

The thrust bearing of this invention is characterised in that the body is retained axially by a number of circumferentially spaced radial pins. By thus rendering the bearing fixed throughout its periphery, the flexure of the body in the axial direction will be reduced, and the bearing surfaces will always be maintained in alignment to distribute the thrust load equally. Referring to the drawing, the bearing



No. 863,299

body carries pads or blocks *A* at its opposite sides. The bearing body is retained axially by two rows of circumferentially spaced pins *B*. The inner ends of the pins form inclined faces *C* engaging conical surfaces on the bearing body. The pins are locked in their endwise direction by bolts *D*. Passed through a bore through the bolt is a screw *E* which is screwed into the pin *B* and has a head wider than the bore. By this arrangement, the pin may be adjusted longitudinally, thereby adjusting the bearing body in an axial direction. If, for instance, the bolts in the right-hand radial plane are screwed inward, and the bolts in the left-hand radial plane are screwed outward in a corresponding degree, then the bearing body will be displaced slightly towards the right. Upon unscrewing, the pin *B* will be pulled out by the screw *E*, the head of which then abuts the bolt *D*.—*March* 22, 1961.

ELECTRONICS

863,755. July 30, 1957.—ELECTRICAL CONTROL DEVICES, Lancashire Dynamo Electronic Products, Ltd., B.E.P. Works, Rugeley, Staffordshire. (*Inventors : Kenneth Arthur Robinson and Gordon Rex Boughton.*)

This invention relates to a control device capable of producing an alternating current output which is suitable, for instance, for driving a servo-motor and which can be reversed in phase under the control of a reversible input signal. The device is composed of two valves or two transistors of the same semiconductor type each arranged to be energised by full-wave current obtained from a common a.c. supply. The two valves or transistors have their inputs oppositely coupled to a common drive circuit and their outputs oppositely coupled to an output circuit connected in a common supply lead. The specification shows two transistors which are connected through a full-wave bridge rectifier to the centre-tapped secondary winding of a transformer with its primary winding connected to an alternating current supply. Each transistor receives an unsmoothed full-wave rectified energising voltage. The connections of both to the centre-tap of the transformer are made through a common lead which includes a winding of a reversible alternating-current servo motor. This winding constitutes a common output circuit to which the transistors are oppositely connected. The motor is of any known or preferred type which will reverse its direction of rotation on phase reversal of the current supplied to this winding. The motor has a further winding which may receive current from the same source as the transformer but shifted in phase by 90 deg. The input of the transistors is derived from a comparison element or other control element of an automatic control system which is capable of generating an alternating-current control signal either in phase with or in phase opposition to the alternating current from which the transformer taps its supply, for the purpose of determining the sense of rotation of the servomotor. The control element is oppositely coupled to the transistors by a transformer. It is a particular advantage of the arrangement that no output transformer is required for coupling the transistors to the motor because the motor winding is connected in a common supply lead of the two transistors. The transistors are preferably so operated that they are both non-conductive when there is no input but become conductive alternately when receiving inputs in phase opposition. The output currents that flow during these alternative half cycles are of opposite sign because the transistors are oppositely connected. The whole output current is thus an alternating current, and is reversed in phase when the drive inputs are reversed in phase. In all forms of the invention, the use of an unsmoothed rectified current supply to the motor greatly reduces the internal dissipation of the transistors or valve as compared with the result which could be obtained by feeding a smoothed direct-current supply to these elements and thus enables larger powers to be controlled by a given size of transistor or valve.—*March* 29, 1961.

INTERNAL COMBUSTION ENGINES

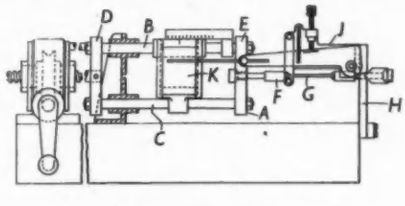
865,350. February 10, 1959.—INTERNAL COMBUSTION ENGINES, General Motors Corporation, Grand Boulevard, Detroit, Michigan, United States of America (assignees of Darl Francis Caris).

This invention relates particularly to the construction and assembly of the crankcase, cylinder block and cylinder head assemblies of internal combustion engines, and especially internal combustion engine cylinder head assemblies. At least one of the assemblies which form the crankcase, cylinder block, and cylinder head comprises a number of members bonded and sealed together by a thermo-setting adhesive. A synthetic plastics material, such as an epoxy resin or buna phenolic resin, which sets at a relatively low temperature is preferred. By the invention a light-weight engine can be readily made by forming one or more assemblies from members of light metal such as aluminium or magnesium alloy.—*April* 12, 1961.

TENSILE TESTING EQUIPMENT

864,990. October 5, 1959.—TENSILE TESTING APPARATUS, Tecquipment, Ltd., Prospect Place, and Joseph Albert Pope, 5, Wortley Hall Close, Nottingham.

This invention relates to improvements in tensile testing apparatus and its object is to provide apparatus which will make a visible record of the extension of a specimen as load is applied and project the record on to a screen. In carrying out this invention the apparatus comprises a base having a sliding frame *A*



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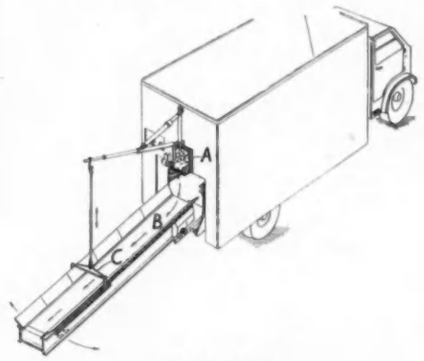
mounted on it. The frame has upper and lower rods *B*, *C*, with their ends connected together by cross members *D*, *E*. The rods slide in bearings in a bracket mounted on the base. The cross member *E* has a gripping device or chuck *F* to hold one end of a specimen test piece *G*. A pillar *H* secured at its lower end to the base also carries a gripping device to hold the other end of the test piece. The upper end of the pillar has an arm *J* which carries a marking point to record its movement on a sheet *K* carried by the frame. The other cross member *D* is connected to suitable means which moves the frame to subject the test piece to tensile stress. As the test piece is subjected to tensile stress the pillar *H* yields slightly about its point of anchorage to the base and causes a deflection of the marking point. The frame *A* will also move and consequently the recording sheet. Movement of the sheet will include any elongation of the test piece so that the marking point will record on the sheet a line giving an indication of elongation against load. The record made on the sheet may be projected on to a screen by a suitable projector comprising a light source behind the sheet a lens in front of the sheet and a screen placed in a suitable position.—*April* 12, 1961.

VEHICLES

865,097. June 24, 1959.—LOADING AND DISCHARGING BULK LOADS ON VEHICLES, Concrete Carrying Company, Ltd., Pilling Street, Rochdale Road, Manchester, 4. (*Inventor : John Crowther.*)

For loading and discharging bulk loads of solid materials on vehicles, a main conveyor is provided in the lower part of the vehicle for feeding the material to the rear, and a secondary conveyor beneath the main conveyor can be extended and adjusted to a convenient position for receiving material from the main conveyor and delivering it as required. Referring to the accompanying drawing the vehicle interior is in the form of a hopper arranged to direct material, such as coke, to a belt conveyor *A* to discharge material at the back. Beneath the conveyor there is a space in which a second conveyor *B* is housed. This second conveyor can be drawn out into the position shown in which it receives material discharged by the upper conveyor and delivers it as required. The free end of the conveyor *B* can be raised or lowered or swung to one side or the other. In the operative position, this conveyor is supported by a yoke *C* having guide rollers at its ends which run in channels on the sides of the conveyor housing. The



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yoke is suspended from an extensible jib which can be raised or lowered by a hydraulic jack, and is mounted on a vertical rod which can turn on brackets secured to the back of the vehicle body. The conveyor *B* is driven by a hydraulic motor and in the operative position the driving end is supported by a swivel bracket.—*April* 12, 1961.

METALLURGY

865,166. November 13, 1959.—HARD SINTERED MATERIALS, Hard Metal Tools Ltd., Torrington Avenue, Canley, Coventry, Warwickshire. (*Inventors : Edward Moor Trent and David Barrie Comins.*)

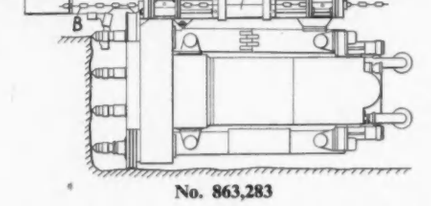
This invention relates to sintered hard materials consisting mainly of alumina. Such materials can be used with advantage as cutting tools, but their resistance either to flank wear or to cratering is not very good. It has been found that if the resistance to flank wear is to be good the grain size of the alumina in the sintered material should be as small as possible, and if the resistance to cratering is to be good the grains should be well bonded together by the other materials present. The problem is complicated by the fact that as the sintering temperature increases the grain size increases also, but that to ensure good wetting of the particles of alumina by a constituent included for bonding purposes the sintering temperature should be high. By using a bonding

agent, comprising a mixture of titanium nitride and a sub-oxide of titanium, materials can be produced in which the resistance to flank wear and the resistance to cratering are both good. A material according to the invention is made by sintering a homogeneous mixture consisting by weight of from 87 per cent to 96 per cent alumina with the remainder (except for impurities) titanium nitride and sub-oxide of titanium and containing at least 2 per cent titanium nitride and at least 2 per cent sub-oxide of titanium. The sub-oxide of titanium is a compound of titanium and oxygen with or without carbon, having the titanium atoms arranged in a face-centred cubic lattice whether or not carbon is present. The oxygen and carbon atoms occupy lattice sites between the titanium atoms. Carbon, if present, may amount to up to 10 per cent and preferably from 5 per cent to 7 per cent by weight of the titanium and oxygen. In general the sintering temperatures of compositions consisting essentially of alumina lie within the range of 1400 deg. Cent. to 1800 deg. Cent In making materials according to the invention the sintering is effected within a limited range of temperature, namely from 1600 deg. Cent. to 1750 deg. Cent., and preferably at 1650 deg. Cent. at least. In order to obtain the best results so far as bonding is concerned, the temperature must be correlated with the precise composition of the mixture. Examples of materials are given in the specification.—*April* 12, 1961.

MINING MACHINES

863,283. September 8, 1959—COAL-CUTTING MACHINES, Crawley Industrial Products, Ltd., Ayling House, King's Road, Horsham, Susses. (*Inventors: Norman Henry Price Dixon and David Marr.*)

The object of this invention is to provide an improved haulage system for moving a machine, such as a cutter-loader, across the coal face in a seam. According to the invention, a cutter-loader, or like machine, has a pair of reciprocating grips designed to clamp on a chain, or like flexible member, anchored across the coal face, the grips being operable alternately to move along the chain on one stroke, grip the chain and move the machine along the chain on the return stroke. A cutter-loader with this haulage system is illustrated by way of example on



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the accompanying drawing. To the ends of the bedframe of the conveyor *A* is anchored a link chain *B* that is stretched across in front of the coal face. Alongside the machine, the chain passes through a haulage unit comprising a bank of four hydraulic cylinders *C* carried by the machine. From diagonally opposite cylinders piston rods *D* and *E* extend to annular cylinders *F*, the inner walls of which are formed by a flexible rubber sleeve through which the chain extends. The cylinders *F* have a pair of offset axial bores to slide on guide rods which extend axially from closed ends of the cylinders *C* to a supporting bracket *G* on the respective end of the machine. Each cylinder *F* has an inlet for oil or compressed air under pressure to constrict the flexible sleeve around the chain. The cylinder and sleeve thus act as a grip under the influence of pressure fluid controlled (by means not shown) in connection with the control of fluid to one pair of the cylinders *C* so that when the piston rods have been thrust to the end of their outward stroke the chain is gripped and on the return stroke of the piston rods the machine is hauled along the chain.—*March* 22, 1961.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS

Mon., May 1.—BOLTON BRANCH: Railway Hotel, Trinity Street, Bolton, "Refrigeration," 7.45 p.m. ★ ESSEX BRANCH: Angel Hotel, Broadway, Ilford, Essex, "Electricity in the 'Ohm'." Miss O. M. Price, 8.15 p.m. ★ LEEDS BRANCH: Great Northern Hotel, Leeds, Films, 7.30 p.m. ★ SHEFFIELD BRANCH: Royal Victoria Hotel, Sheffield, "Historical Water Power in the Don Valley," G. F. Jones, 7.30 p.m.

Tues., May 2.—READING AND DISTRICT BRANCH: Southern Electricity Board, Vastern Road, Reading, Films, 7.30 p.m.

Wed., May 3.—HALIFAX BRANCH: Crown Hotel, Horton Street, Halifax, "Solderless Connectors," A. S. Ferguson, 7.45 p.m. ★ SOUTH EAST LONDON BRANCH: Eltham Green School, Queenscroft Road, Eltham, London, S.E.9, "Cables and their Uses," A. Richardson, 7.45 p.m. ★ MANCHESTER BRANCH: Engineers' Club, Albert Square, Manchester, "Marine Electrical Auxiliaries," J. H. B. Raw, 7.15 p.m. ★ PRESTON BRANCH: R.A.F.A. Club, East View, Preston, "Resins in Industry for Electrical Components," H. Davies, 7.30 p.m.

Thurs., May 4.—BRIGHTON, HOVE AND DISTRICT BRANCH: New Imperial Hotel, First Avenue, Hove, Sussex, "Production of a Technical Journal," R. Baldwin, 7.30 p.m.

Fri., May 5.—LIVERPOOL AND DISTRICT BRANCH: Industrial Development Centre, M.A.N.W.E.B., Paradise Street, Liverpool, 1, "Particle Accelerators," B. S. Halliday, 7.30 p.m. ★ STOKE AND CREWE BRANCH: Grand Hotel, Harley, "Plastics in the Electrical Industry," A. J. J. Moulam, 7.30 p.m.

BRITISH INSTITUTION OF RADIO ENGINEERS

Wed., May 3.—COMPUTER AND RADAR GROUPS: University College, London, Symposium on "Computer Control of Air Traffic," 3 p.m.

ELECTRICAL ASSOCIATION FOR WOMEN

Mon. and Tues., May 1 *and* 2.—Thirty-sixth Annual Conference, Tues.: Kingsway Hall, London, W.C.2, Annual General Meeting, 10.30 a.m.

ILLUMINATING ENGINEERING SOCIETY

Mon., May 8.—LEEDS CENTRE: Guildford Hotel, The Headrow, Leeds, Annual General Meeting, 6.30 p.m.

INDUSTRIAL FINISHES EXHIBITION

Mon. to Thurs., May 8 *to* 11.—Earls Court, London, S.W.5, First International Exhibition.

INSTITUTE OF MATERIALS HANDLING

Wed. to Fri., May 10 *to* 12.—Prince of Wales Hotel, Southport, Second International Conference.

INSTITUTE OF NAVIGATION

Fri., May 12.—Royal Geographical Society, 1, Kensington Gore, London, S.W.7, "Airborne Weather Radar," R. C. Alabaster and P. L. Stride, 5.15 p.m.

INSTITUTE OF PETROLEUM

Wed., May 3.—61, New Cavendish Street, London, W.1, "Recent Developments in Arc Welding as Applied by the Petroleum Industry," W. K. B. Marshall and V. I. Holmes, 5.30 p.m.

INSTITUTE OF REFRIGERATION

Thurs., May 4.—The Institute of Marine Engineers, The Memorial Building, 76, Mark Lane, London, E.C.3, "Metals for Refrigeration and Other Low Temperature Installations," G. P. Smedley, 5.30 p.m.

INSTITUTE OF ROAD TRANSPORT ENGINEERS

Fri., May 12.—SOUTH WALES CENTRE: South Wales Institute of Engineers, Park Place, Cardiff, "The History and Development of Octane Motor Spirit," J. C. Street, 7.15 p.m.

INSTITUTE OF WELDING

To-day April 28.—54, Princes Gate, Exhibition Road, London, S.W.7, Spring Meeting, Theme "Recent Developments in the Welding and Allied Processes."

INSTITUTION OF CIVIL ENGINEERS

Tues., May 2.—Great George Street, Westminster, London, S.W.1, "New Tunnels near Potters Bar in the Eastern Region of British Railways," A. K. Terris and H. D. Morgan, 5.30 p.m.

Wed. and Thurs., May 3 *and* 4.—Great George Street, Westminster, London, S.W.1, Joint Meeting with the Institutions of Mechanical and of Electrical Engineers, Railway Modernisation Conference.

Tues., May 9.—Great George Street, Westminster, London, S.W.1, "Auckland Harbour Bridge—Design," G. Roberts and O. A. Kerensky, and "Construction," H. Shirley Smith and J. F. Pain, 5.30 p.m.

Thurs., May 11.—Great George Street, Westminster, London, S.W.1, Joint Meeting with the Institute of Landscape Architects, "Collaboration Between Engineers and Landscape Architects," C. S. Chettoe and G. A. Jellicoe, 5.30 p.m.

INSTITUTION OF ELECTRICAL ENGINEERS

To-day, April 28.—SOUTH MIDLAND EDUCATION DISCUSSION CIRCLE: College of Advanced Technology, Gosta Green, Birmingham, Discussion on "The Selection of Engineering Students," opened by W. D. Furneaux, 6 p.m.

Sat., April 29.—LONDON GRADUATE AND STUDENT SECTION: Visit to London Fire Brigade, Albert Embankment, London, 2.30 p.m.

Mon., May 1.—ARBORFIELD DISTRICT MEETING: Unit Cinema, 3 (Tels.) Training Bn., R.E.M.E., Arborfield, Berks., "Aural Properties of Spaced Loudspeaker Systems," J. B. Helder, 7 p.m. ★ ELECTRONICS AND COMMUNICATIONS SECTION: Savoy Place, London, W.C.2, "Progress Report on the Development of a Photo-Electric Beam Index Colour Television Tube and System," R. Graham, J. W. H. Justice and J. K. Oxenham, 5.30 p.m. ★ EAST ANGLIAN SUB-CENTRE: Assembly House, Norwich, Annual General Meeting, and "Generator/Motor Problems in Pumped-Storage Installations," J. H. Walker, 7.30 p.m. ★ SOUTH MIDLAND CENTRE: James Watt Memorial Institute, Birmingham, "Silicon Power Rectifiers," A. J. Blundell, A. E. Garside, R. G. Hibberd and I. Williams, 6.30 p.m.

Tues., May 2.—MEASUREMENTS AND ELECTRONICS SECTION: Savoy Place, London, W.C.2, "Structural Properties and Applications of Evaporated Metal Films," D. W. Pashley. "Deposition of Evaporated Non-Magnetic Films," J. R. Balmer, 5.30 p.m. ★ NORTHERN IRELAND CENTRE: David Keir Building, Queen's University, Stranmillis Road, Belfast, 9, Annual General Meeting, 6.30 p.m. ★ SOUTHERN CENTRE: Technical College, Farnborough, "The Potentialities of Artificial Earth Satellites for Radiocommunication," W. J. Bray, 6.15 p.m.

Wed., May 3.—LONDON GRADUATE AND STUDENT SECTION: All-day visit, London Airport, 8.45 a.m. ★ TEES-SIDE SUB-CENTRE: Cleveland Scientific and Technical Institution, Middlesbrough, Annual General Meeting. "An Analytical Approach to Industrial Lighting," W. Imrie-Smith, 6.30 p.m. ★ NORTH LANCASHIRE SUB-CENTRE: N.W.E.B. Demonstration Theatre, Friargate, Preston, Annual General Meeting, "Electronic Aids to Banking and Commerce," R. Feinberg, 7.30 p.m.

Wed. and Thurs., May 3 *and* 4.—RAILWAY MODERNISATION CONFERENCE: Institution of Civil Engineers, Great George Street, Westminster, London, S.W.1, Joint Conference with the Institutions of Civil and Mechanical Engineers.

Thurs. to Sun., May 4 *to* 7.—ELECTRONICS AND COMMUNICATIONS SECTION: Visit to Cologne.

Fri., May 5.—MEDICAL ELECTRONICS DISCUSSION GROUP: Savoy Place, London, W.C.2, Discussion on "Artificial Muscles," opened by A. B. Kinnear Wilson, 6 p.m.

Sat., May 6.—LONDON GRADUATE AND STUDENT SECTION: Visit to A.E.I., Ltd., Willesden, 10.30 a.m. ★ MEASUREMENT AND CONTROL SECTION: Visit to Leatherhead.

Mon., May 8.—ELECTRONICS AND COMMUNICATIONS SECTION: Savoy Place, London, W.C.2, "The Corona-Discharge and its Application to Voltage Stabilisation," E. Cohen and R. O. Jenkins, "Impedance Frequency Characteristics of Glow-Discharge Reference Tubes," F. A. Benson and P. M. Chalmers, "Comparison of Argon, Krypton and Xenon as Admixtures in Neon Glow-Discharge Reference Tubes," F. A. Benson and G. P. Burdett, 5.30 p.m.

Tues., May 9.—NORTH WESTERN CENTRE: Engineers' Club, Albert Square, Manchester, Annual General Meeting, "The Protection of High-Voltage Systems from Lightning Faults," R. H. Golde, 6.15 p.m.

Wed., May 10.—SUPPLY SECTION: Savoy Place, London, W.C.2, "Electricity Supply in India and its Future," M. Datta, 5.30 p.m.

INSTITUTION OF LOCOMOTIVE ENGINEERS

Wed. to Fri., May 10 *to* 12.—GOLDEN JUBILEE CELEBRATION: May 10: Reception by President, Mr. D. C. Brown, 12 noon; Lunch, Dorchester Hotel, 1 p.m.; The Sir Seymour Biscoe Tritton Lecture to be given by Sir Brian Robertson, Bt., at the Institution of Mechanical Engineers, 1, Birdcage Walk, London, S.W.1, 5 p.m.; May 11: All-day Visit; May 12: Exhibition of Locomotives at Marylebone Goods Yard, London, N.W.1, morning; Dinner, Dorchester Hotel, 7.15 p.m.

INSTITUTION OF MECHANICAL ENGINEERS

To-day, April 28.—WESTERN BRANCH: Royal Naval Engineering College, Manadon, Plymouth, "Hovercraft," G. J. Thomson, 7 p.m.

Sat., April 29.—EASTERN GRADUATES' SECTION: Visit to the site of the Atomic Power Station, Sizewell, 9.45 a.m.

Wed., May 3.—SOUTHERN BRANCH: Visit to Plessey Company, Ltd., New Lane, Havant, 2.30 p.m.

Wed. and Thurs., May 3 *and* 4.—RAILWAY MODERNISATION CONFERENCE: Institution of Civil Engineers, Great George Street, Westminster, London, S.W.1, Joint Meeting with the Institutions of Civil and Electrical Engineers.

Sat., May 6.—SOUTHERN BRANCH GRADUATES' SECTION: Visit to Northfleet Generating Station, Gravesend, 10 a.m.

Tues., May 9.—EASTERN BRANCH GRADUATES' SECTION: Visit to Marston Valley Brick Company, 7.30 p.m.

Wed., May 10.—SOUTHERN BRANCH GRADUATES' SECTION: Visit to Stirling Cables, Ltd., Aldermaston, 2.30 p.m.

INSTITUTION OF PLANT ENGINEERS

To-day, April 28.—BIRMINGHAM BRANCH: Imperial Hotel, Temple Street, Birmingham, "Fibre Glass Reinforced Plastics," G. O. Gurney, 7.30 p.m.

Tues., May 2.—LONDON BRANCH: Royal Society of Arts, John Adam Street, Adelphi, W.C.2, "Paints and the Preservation of Steel," E. W. Marshall, 7 p.m. ★ PETERBOROUGH BRANCH: White Lion Hotel, Church Street, Peterborough, Members' Papers, 7.30 p.m.

Wed., May 3.—SOUTHERN BRANCH: Polygon Hotel, Southampton, "Industrial Floors," W. J. Warlow, 7.30 p.m.

INSTITUTION OF PRODUCTION ENGINEERS

Fri., May 5.—WALES REGION: South Wales Institute of Engineers, Park Place, Cardiff, One-Day Conference on "The Conservation of Materials," 9 a.m. to 4.30 p.m.

Wed., May 10.—MIDLANDS REGION: Winter Gardens and Raven Hotel, Droitwich, One-Day Conference on "Product Development."

INSTITUTION OF STRUCTURAL ENGINEERS

To-day, April 28.—MIDLAND COUNTIES BRANCH: Byng Kendrick Suite, College of Advanced Technology, Gosta Green, Birmingham, 6, "Modern Urban Highway Structures," G. B. Smedley, 6.30 p.m.

IRON AND STEEL INSTITUTE

Wed. and Thurs., May 3 *and* 4.—Institution of Mechanical Engineers, 1, Birdcage Walk, Westminster, London, S.W.1, Annual General Meeting followed by technical sessions devoted to the use of computers in the iron and steel industry and to the Brymbo oxygen steelmaking process.

Wed. and Thurs., May 3 *and* 4.—Church House, Great Smith Street, London, S.W.1, The Iron and Steel Institute and The Institute of Metals joint symposium on "Structural Processes in Creep."

NATIONAL PHYSICAL LABORATORY

Wed. and Thurs., May 10 *and* 11.—Teddington, Middlesex, Open Days.

OLD CENTRALIANS

Mon., May 8.—City and Guilds College, Exhibition Road, South Kensington, London, S.W.7, Annual General Meeting, 5.30 p.m.

ROYAL AERONAUTICAL SOCIETY

Thurs., May 4.—4, Hamilton Place, London, W.1, Annual General Meeting, 6.30 p.m.

Fri., May 5.—ROTORCRAFT SECTION: 4, Hamilton Place, London, W.1, "The Helicopter—the First of the VTOL Aircraft," R. Hafner, 6 p.m.

Mon., May 8.—HISTORICAL GROUP: 4, Hamilton Place, London, W.1, A continuation of the discussion held on April 10, "A Quiz on Little Known Early Aircraft," 7 p.m.

Tues., May 9.—4, Hamilton Place, London, W.1, "Structural Weight Estimations for Novel Configurations," M. E. Burt, 7 p.m.

ROYAL INSTITUTION OF CHARTERED SURVEYORS

Mon., May 1.—ORDINARY GENERAL MEETING: 12, Great George Street, Westminster, London, S.W.1, "Valuers, Quantity Surveyors and Architects—Combined Operations or Eternal Triangle?" 5.45 p.m.

ROYAL SOCIETY OF ARTS

Wed., May 10.—John Adam Street, London, W.C.2, "The Future Pattern of University Education in the United Kingdom," J. S. Fulton, 6 p.m.

SOCIETY OF CHEMICAL INDUSTRY

Mon., May 8.—CORROSION GROUP: 14, Belgrave Square, London, W.1, Annual General Meeting, 6 p.m.

SOCIETY OF ENGINEERS

Mon., May 1.—Engineering, Marine, Welding and Nuclear Energy Exhibition, Olympia, London, "New Jet Propulsion for Boats," R. H. Bound, 5.30 p.m.

TELEVISION SOCIETY

To-day, April 28.—Cinematograph Exhibitors' Association, 164, Shaftesbury Avenue, London, W.C.2, Annual General Meeting, 7 p.m.